ASHRAE – Save Energy Now Presentation Series

Introduction

Course Objective

According to the EPA's energy report to Congress, Data Centers account for 1.5% of the total United States' power consumption. The demand from the Data Center industry is increasing by 12.5% annually.

This presentation series will:

- Provide training in opportunities for improving energy efficiency in Datacom facilities
- Focus on the Data Center Owner / Operator.
- Support the DOE vision to create guidelines for continuous improvement
- Inspire data center owners to take action now to begin reducing energy

Course Outline

- Data Center; What Makes Them Different Than Other Projects
- Cooling Services / Systems
- Electrical Services / Systems
- IT Requirements, Interfaces, Etc.
- Summary
- Data Center Efficiency Programs To Support Federal Projects

ASHRAE – Save Energy Now Presentation Series

Data Centers: What Makes Them Different Than Other Projects?

Opening Comments / Agenda

- **Data Centers compared to other facilities**
  - What are the similarities and differences?
- **The Holistic Approach**
  - Overcoming the disconnect between IT & Facilities
- **Data Center Load Variation**
  - Reliability & Occupancy Variation Impact on the Load
- **Some Data Center Design Considerations**
  - Right Sizing, Right Timing & Future-Proofing
- **A High Level Overview of a Data Center**
- **SLA – Service Level Agreement; Power & Cooling as Services**

Data Centers vs. Other Facilities: What are the similarities?

Depending on the size of the data center, the buildings are SIMILAR in construction to offices or warehouses.

Also, MOST of the power and cooling equipment is essentially the same as found on other types of construction:

- Cooling Equipment (chillers, cooling towers, condensers, air handlers, fans, pumps, heat exchangers, water filtration)
- Power Equipment (switchgear, switchboards, panelboards, transformers, generators, transfer switches, filters)

Data Centers vs. Other Facilities: What are the differences?

SOME of the power and cooling equipment is unique to data centers and not used very much outside of data centers:

- **Cooling Equipment**
  - Drycoolers
  - Computer Room Air Conditioning (CRAC) units
- **Power Equipment**
  - Uninterruptible Power Supply (UPS) units
  - Static Switches
  - Power Distribution Units (PDUs)

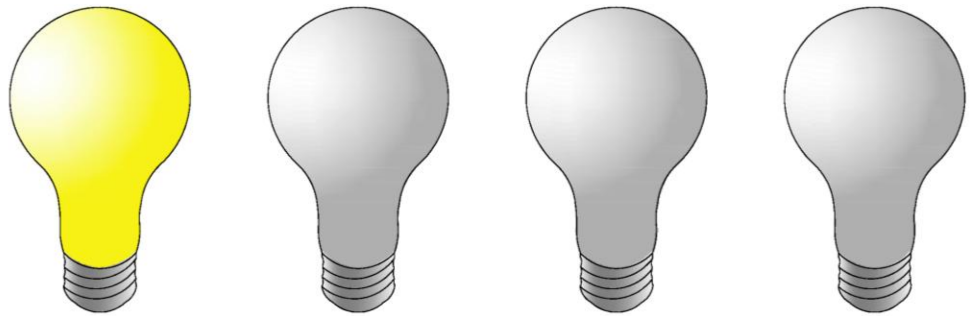
Data Centers vs. Other Facilities: What are the differences?

In addition, data centers have UNIQUE design challenges

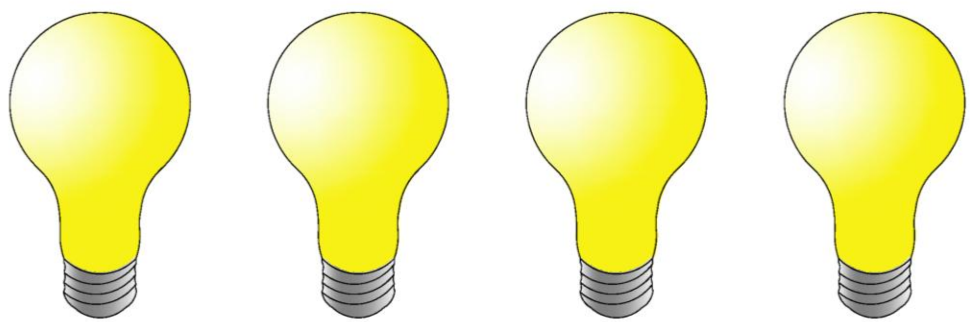
- Extremely high energy density ranging from **50** to **1,000** watts per square foot (office buildings are typically **10** watts per square foot)
- Data Centers are MISSION CRITICAL and have an increased emphasis on RELIABILITY, AVAILABILITY and CONCURRENT MAINTAINABILITY
- Data Centers have UNINTERRUPTIBLE energy requirements (i.e. uninterruptible power AND uninterruptible cooling)
- Data center power loads are CONTINUOUS 24 hours per day, 7 days per week, 365 days per year (not variable based on business hours)

Continuous Operation Yields Energy Saving Opportunities

Commercial
(2200 hrs / year)



Data Center
(8800 hrs / year)



The Holistic Approach - Introduction

IT / Design & Construction / Facilities & Operations Industries have independent targets and different emphases.

A successful data center project benefits from the seamless integration of many traditionally isolated industries.

All of these industries play a critical role and need to be considered holistically including the assessment of tradeoffs in:

- Cost (capital expenditure and operating expenditure)
- Schedule (speed to market / speed to deployment)
- Reliability / Availability
- Future Flexibility (avoiding premature obsolescence)
- Energy Efficiency

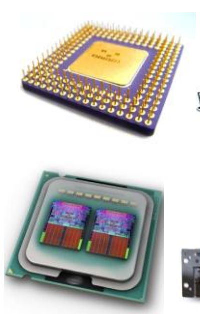
The Holistic Approach – IT vs. Facilities

Topic	IT Industry	Facilities Industry
End Product	Factory Fabricated	Field Fabricated (typically custom, no prototype)
Environment Where the Product is Produced.	Inside a factory with desired environmental control.	Outdoors and indoors with limited environmental control (e.g. weather)
Labor	Factory Workers (performance well measured)	Construction Workers (little performance measurement)
Quality Control	Minimal Defects	Many more defects than Factory Built
Product Based On Initially Creating A Prototype?	Common	Seldom
Regulatory Requirements, Interpretation & Enforcement	Reasonably Consistent	Less predictable, Building Inspector's views often differ

The Holistic Approach – Industry Boundaries

IT Industry ⟷ **Facilities Industry**

Chip / CPU / Board	Server / Packaging	Rack / Cabinet	Row / Server Floor	Central Plant / Equipment Yard	Utility Plant / Substation






The Holistic Approach – A Moving Target

Data Centers can be thought of as commercial buildings that house IT equipment (computers).

- Commercial buildings' power & cooling infrastructure are typically built to last **15** to **25** years
- IT equipment typically requires replacement every **3** to **5** years

Therefore, to avoid premature obsolescence, a Data Center realistically needs to be able to support **MULTIPLE GENERATIONS** of IT equipment.

Future IT equipment power density is targeted by conflicting trends:

- Continued Compaction (speed, capacity, compute focus)
- Reduced Compaction (larger but more efficient equipment)

The Holistic Approach – Choosing Design Criteria

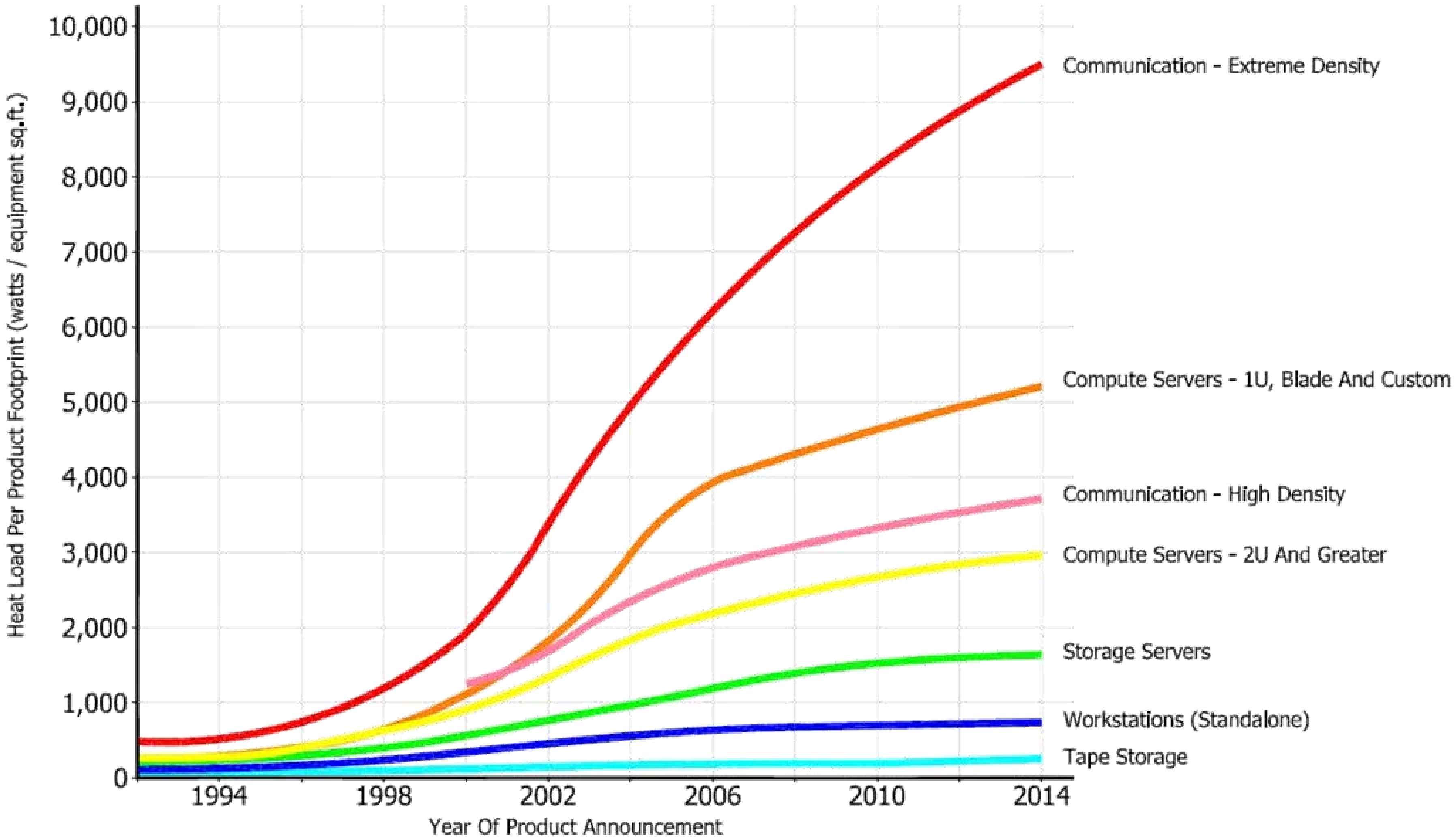
Future IT equipment power density may continue to trend higher & higher. Therefore what is considered to be the CORRECT design criteria?

- Generation 1 (Day 1),
- Generation 5 (Ultimate)
- A hybrid or something else?

Other considerations for determining the design criteria:

- Green Considerations (Energy Efficiency and Sustainability)
- Carbon Cap and Trade Potential
- Capex and/or Total Cost of Ownership (TCO)
- Project Location, Climate and Availability of Utility Capacity

The Holistic Approach – ASHRAE Trend Chart



Data Center Load Variation

There are many variables that impact the load of a Data Center including:

- **Reliability**
  - Redundant Components, Concurrently Maintainable, Fault Tolerant
- **Occupancy**
  - In the Rack, in the Row, on the Floor
  - Specific Hardware Configuration (CPU, RAM, Hard Drive, etc.)
- **Utilization**
  - Idle vs. Fully Utilized
  - Software / Application
  - Hardware Virtualization
  - Network Configuration

Data Center Load Variation - Impact of Redundant Components

Redundancy Strategy	Quantity Of Units Required To Meet Load (N)									
	1	2	3	4	5	6	7	8	9	10
N	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
N+1	50%	67%	75%	80%	83%	86%	88%	89%	90%	91%
2N	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
2(N+1)	25%	33%	38%	40%	42%	43%	44%	44%	45%	45%

Redundancy results in PERMANENT part load conditions.

The Holistic Approach – A Moving Target

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Future IT equipment power density is targeted by conflicting trends:

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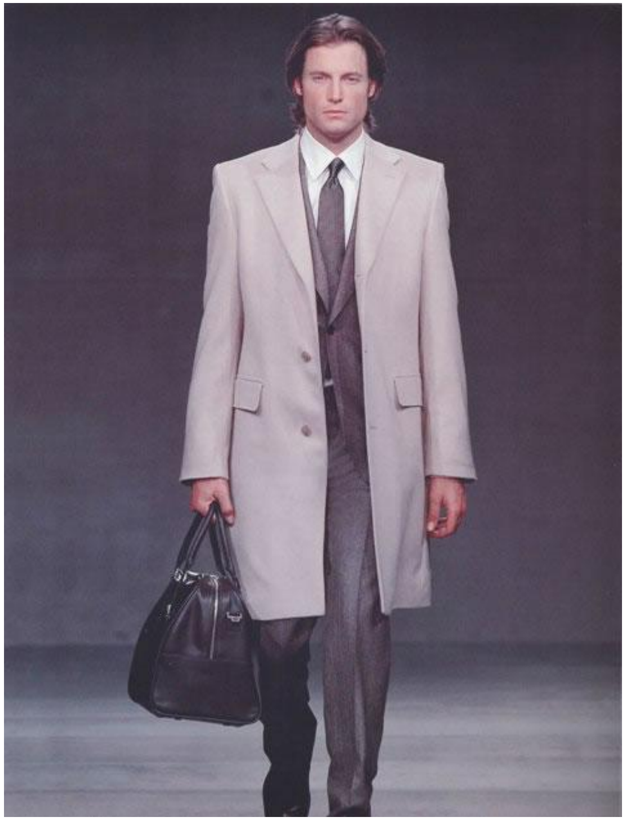
- Reduced Compaction (larger but more efficient equipment)

Data Center Design – Right Sizing

What is the right size for a data center and its systems?



Data Center Design – Right Timing

When do you provision for and implement an increase in data center load?

Show & Tell

Video – 1

Data Center Design – Planning for the Future

The following variables / criteria necessitates the need to establish tradeoffs that plan for the future in all data center designs:

- The ever changing IT equipment and applications
  (what should the data center capacity be?)
- Stranding capacity / increased first cost consideration
  (premature spending – over-provisioning)
- Avoiding the premature obsolescence of under-provisioning
  (multiple generations of IT upgrades to consider)
- Minimizing future disruptions
  (upgrading an OPERATING data center WITHOUT compromising the reliability / availability / concurrent maintenance criteria)

Data Center Design – Planning for the Future

Example of Cost Impact of Constructing for Future Needs				
Scenario	Initial System Design	Construction Cost (Expressed as Relative Cost)		
		Initial	1st Major Refresh / Upgrade	Total
		A	B	C = A + B
1	Only for Today's Needs	1	0.75	1.75
2	Provisions to Scale	1.1	0.25	1.35
3	Include Capacity for Future	1.25	0	1.25

Data Center Design – Capacity Planning for the Future

Areas to Plan

- Servers
- Network
- Power
- Cooling
- Space

Major Steps

- Clearly Define Service Level Agreements (SLAs)
- Analyze Current Capacity
- Predict Future Capacity for at least **3** Generations of IT Equipment

Data Center Design – Capacity Planning for the Future

Topic	Day 1 Need (KW)	IT Generation Refreshes (KW)			
		First	Second	Third	Fourth

Data Center Design – Capacity Planning for the Future

Topic	Day 1 Need (KW)	IT Generation Refreshes (KW)			
		First	Second	Third	Fourth
SLA – client 1	200	400	500	500	0
Storage	1,000	500	500	500	500
SLA – client 2	2,000	300	400	0	1,500
Network Gear	500	200	100	500	200

Data Center Design – Annual Load Profiling

Annual IT Load Profile per Zone or Cluster					
Zone or Cluster	Percent of Annual Hours at Each Load Level				
	10% Load	25% Load	50% Load	75% Load	100% Load

Data Center Design – Annual Load Profiling

Annual IT Load Profile per Zone or Cluster					
Zone or Cluster	Percent of Annual Hours at Each Load Level				
	10% Load	25% Load	50% Load	75% Load	100% Load
1	10	25	40	20	5
2	0	20	50	15	15
3	20	30	10	35	5
4	15	15	20	45	5
5	5	50	40	5	5
6	15	25	20	38	2

Data Center Design – Planning Load Growth

IT Life Cycle Load Growth				
Zone or Cluster	Percent Load or Load in KW			
	Day 1	Year 1	Year 2	Final Year

Data Center Design – Planning Load Growth

IT Life Cycle Load Growth				
Zone or Cluster	Percent Load or Load in KW			
	Day 1	Year 1	Year 2	Final Year
1	5%	50%	75%	95%
2	15%	40%	85%	98%
3	5%	50%	80%	99%
4	20%	50%	90%	97%
5	30%	60%	90%	98%
6	15%	20%	60%	70%

Data Center Design – Lifetime Load Growth

Load Growth during Facility Lifetime						
Zone or Cluster	Peak Load in KW					
	IT Generation 1		IT Generation 2		IT Generation 3	
	Start	End	Start	End	Start	End

Data Center Design – Lifetime Load Growth

Load Growth during Facility Lifetime						
Zone or Cluster	Peak Load in KW					
	IT Generation 1		IT Generation 2		IT Generation 3	
	Start	End	Start	End	Start	End
1	600	800	500	900	500	1,000
2	500	900	600	1,000	900	1,600
3	200	300	550	1,200	800	1,400
4	300	400	750	1,100	900	1,900
5	200	800	800	1,500	500	1,600
6	600	1,000	900	1,100	1,100	1,700

Data Center Design – Availability Strategy

Uptime / Reliability Requirement per Application or Zone				
Zone, Cluster, or Application	Uptime Institute Reliability Tier			
	Tier 1	Tier 2	Tier 3	Tier 4

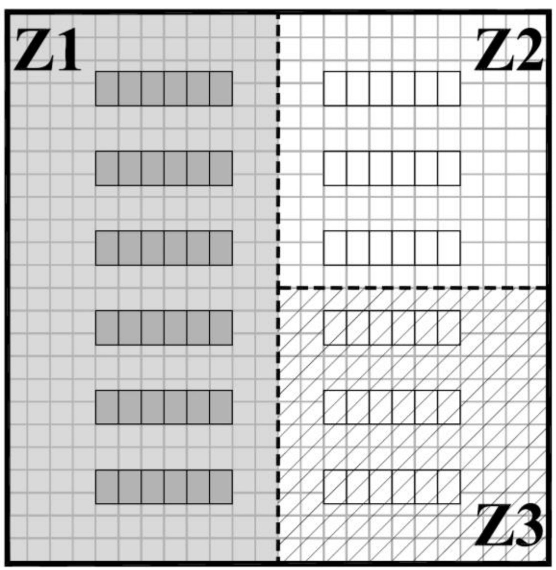
Data Center Design – Availability Strategy

Uptime / Reliability Requirement per Application or Zone				
Zone, Cluster, or Application	**Uptime Institute Reliability Tier**			
	Tier 1	**Tier 2**	**Tier 3**	**Tier 4**
1		x		
2	x			
3			x	
4				x
5				x
6		x		

Data Center Design – Partitioning Into Zones

Dividing one room into many zones facilitates the use of various IT, power and cooling strategies.

Zones can also have different capacity plans and growth strategies.



Room with 3 Zones – Density Example

Z1 - Low Density Zone	(6 Rows)
Z2 - Medium Density Zone	(3 Rows)
Z3 - High Density Zone	(3 Rows)

Data Center Design – Modular Overview

Utilizing modular systems can help capacity planning by increasing system flexibility.

Consider Day 1 initial deployment needs versus ultimate deployment – will cooling needs increase slowly or rapidly?

Modular cooling solutions can be implemented in phases:

- Day 1 install can be faster than construction of a full central plant
- Eliminate unused equipment
- Expand cooling capacity as needed to support IT

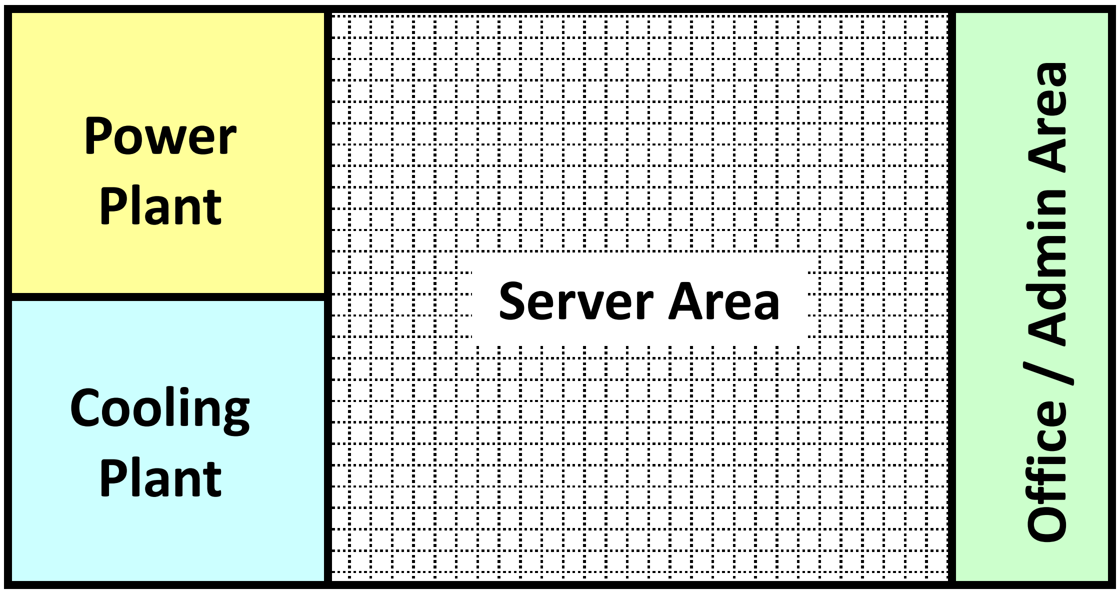
Data Center Design – Retrofit Versus New Construction

Many advantages exist for implementing new technology, including hardware consolidation, increased density, hot swapping, redundant components, and reduced TCO.

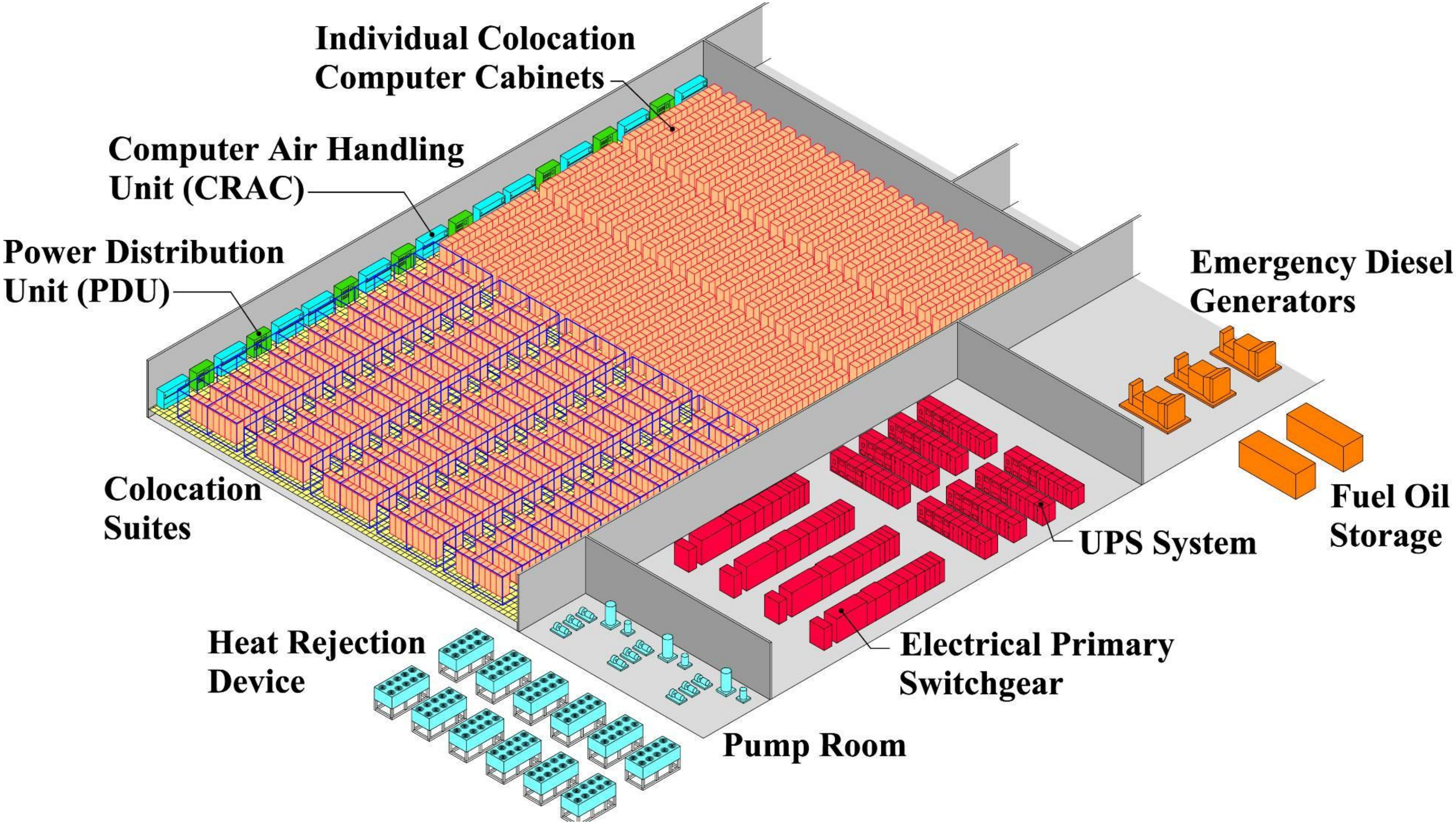
Facilities may NOT be designed to accommodate high density loads and can require major cooling system upgrades.

Due to the IT refresh rate, retrofit construction cost can end up being equal to new construction after multiple generations of IT equipment.

Data Center Overview – Simplified Space Plan



Data Center Overview



Data Center Overview – Power and Cooling Systems

Cooling Systems

- Heat Rejection (e.g., cooling tower)
- Cooling Equipment (e.g., chiller)
- Terminal Equipment (e.g., CRAC unit)
- Economizer (e.g., heat exchanger)

Power Systems

- Primary Power Source (Utility)
- Secondary / Emergency Power Source (Generator)
- Uninterruptible Power Source (UPS)
- Power Distribution

Key Takeaways

1. Data Centers have SIGNIFICANTLY DIFFERENT EMPHASES than other types of facilities.
2. Data Center designs have to be HOLISTIC and therefore require the SEAMLESS INTEGRATION of many traditionally ISOLATED industries.
3. Data Center designs require much more FUTURE-PROOFING than other facilities to support MULTIPLE GENERATIONS of IT equipment.
4. The CONTINUOUS OPERATION mode of Data Centers present a SIGNIFICANT OPPORTUNITY for energy efficiency consideration.
5. Data Centers focus on MISSION CRITICAL RELIABILITY through the use of redundant components is in CONFLICT with energy efficiency.

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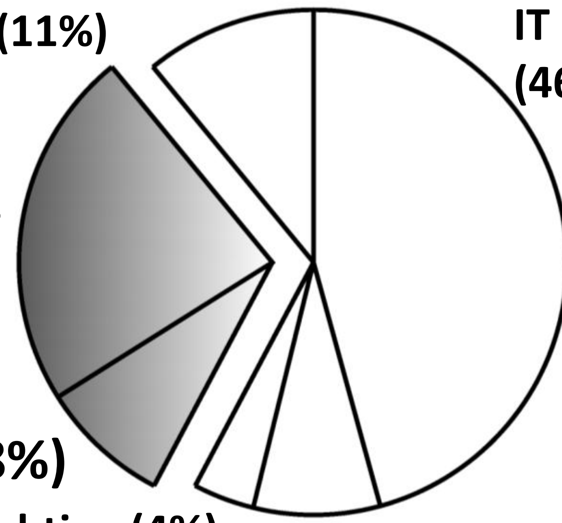
Cooling Services / Systems

Overview of Topics

There is a significant opportunity for energy savings in BOTH new & existing datacenters through an optimization of the design / operation of the cooling systems.

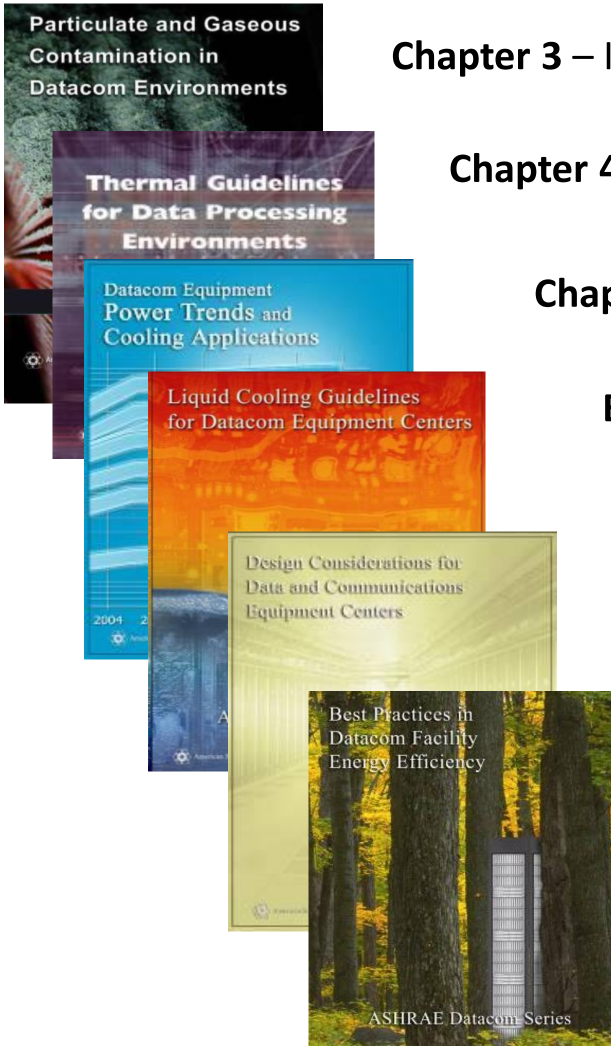
- Air or Water Cooling
- Cooling Systems
- Cooling Equipment
- Economizer Cycles
- Air Distribution
- Airflow Optimization
- Liquid Cooling
- Controls & Energy Mgmt



Typical Data Center Power Allocation

Source: LBNL

Pertinent Chapters From ASHRAE Datacom Series



Chapter 3 – Industry Specifications and Guidelines

Chapter 4 – Equipment Placement & Airflow Patterns

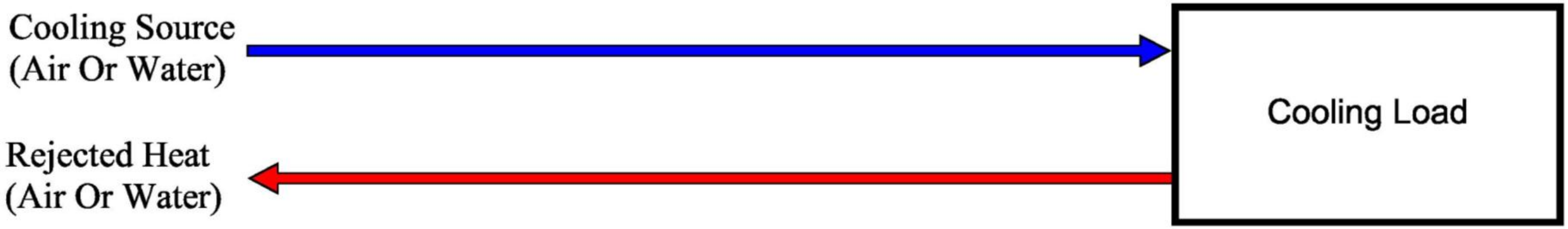
Chapter 4 – Air Cooling Of Computer Equipment

Entire Book

Chapter 4 – Computer Room Cooling Overview
Chapter 5 – Air Distribution

Chapter 3 – Mechanical Equipment and Systems
Chapter 4 – Economizer Cycles
Chapter 5 – Airflow Distribution

Air or Water Cooling?



Starting from outward and tracing the cooling service path down to the load, it starts with either air or water.

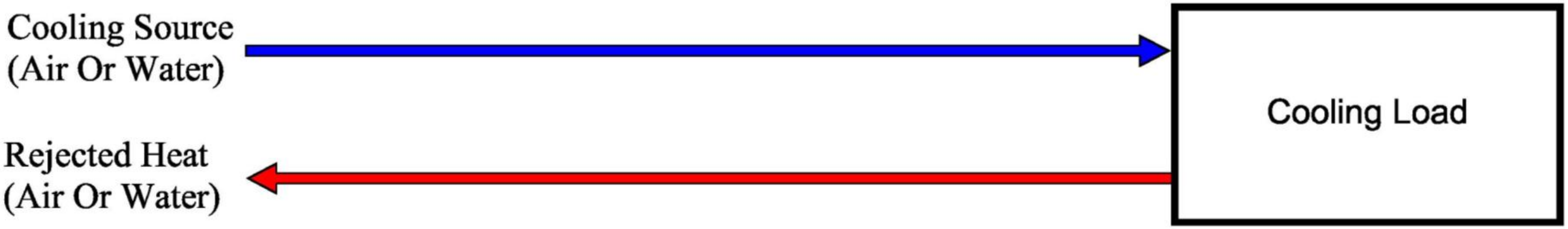
Air or water is used to cool the load or some portion of the cooling process such as the heat rejection from cooling equipment.

An assessment of the air & water is the first step in determining the possibilities for cooling and the possibilities for optimized energy usage.

What can the available WATER be used for?

What can the available AIR be used for?

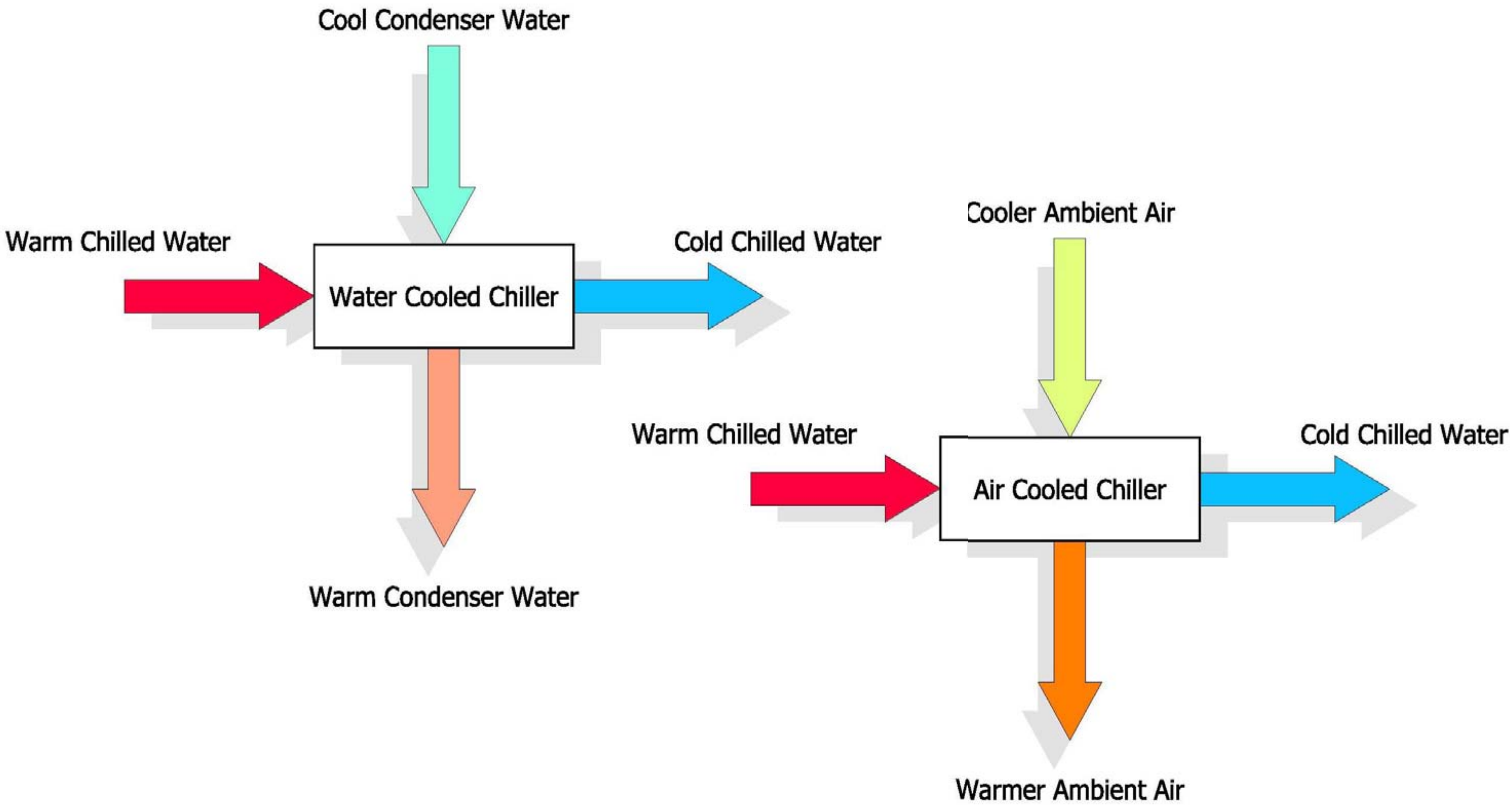
Air or Water Cooling?



Air Or Water Cooling The Load

Air Or Water Cooling The Cooling Equipment

Air or Water Cooling - Chillers



Air or Water Cooling - Key considerations

What is the maximum inlet temperature that can cool your IT equipment?

- Depends on business strategy regarding IT equipment inlet temperature (e.g. at what point within the ASHRAE Recommended or Allowed Temperature is acceptable?)

Can excursions beyond designated IT equipment inlet temperature be tolerated?

- Do you design for worst possible condition / event or allow some excursions?

If excursions are acceptable, how will they be handled?

- Throttle back or turn off IT equipment (application is not critical or can be diverted to another location)
- Provide supplemental cooling capacity (e.g. mechanical cooling)
- 'Ride through' excursion while monitoring IT equipment & system performance
- Provide cooling system thermal storage

Can AIR be used to Cool IT Equipment?

Step 1 – Establish the Basics

Step 2 – Climate Analysis

Step 3 – Air Quality Analysis

Step 4 – High Level TCO Analysis

These steps can vary from professional judgment to in-depth analysis

Step 1 – Establish the Basics

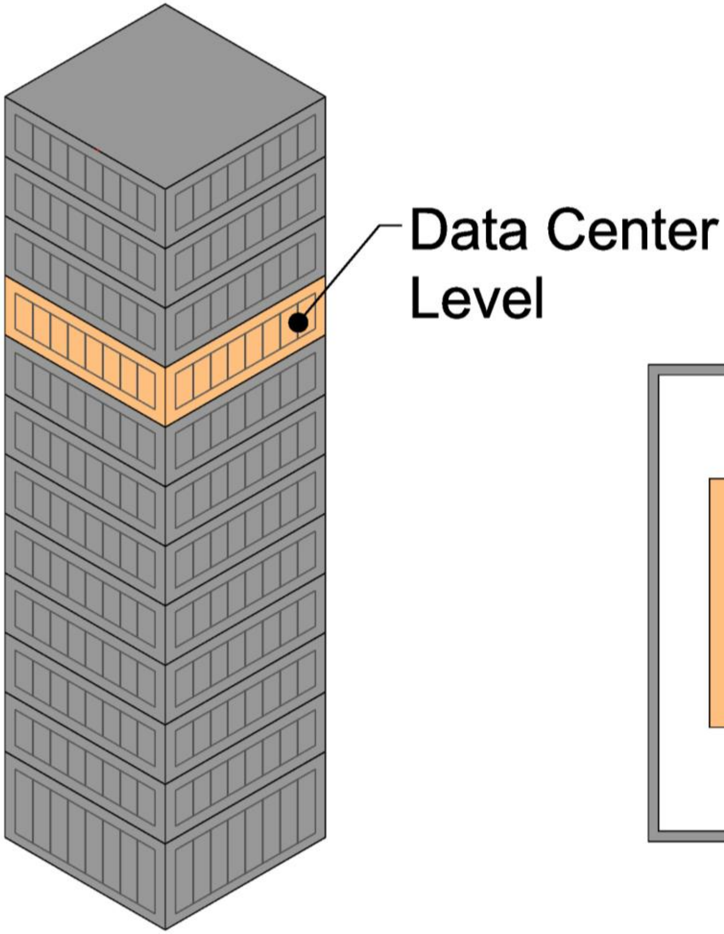
Can outdoor air be used to cool your IT equipment?

- Varies depending on climactic conditions and cleanliness of outside air .

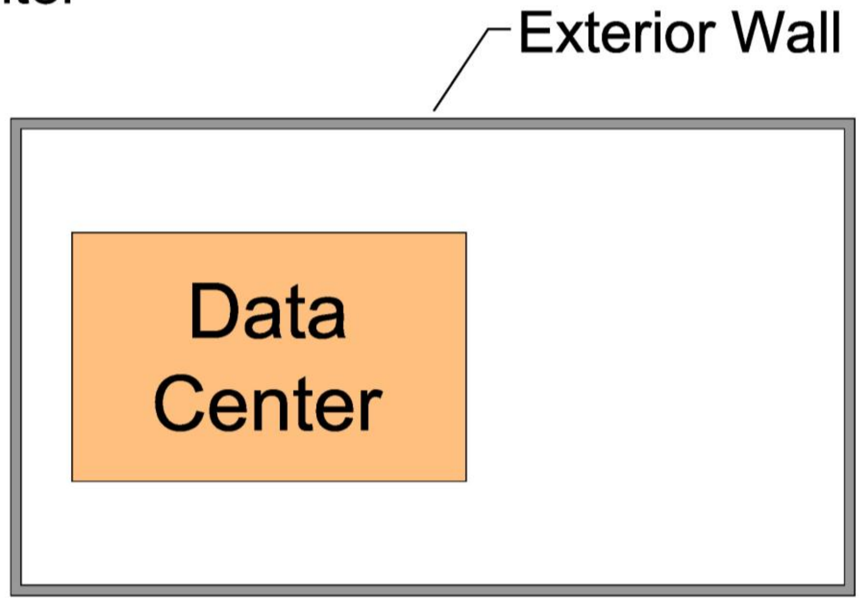
What is the maximum volume of outside air that can reach your IT equipment?

- Varies depending on access and physical conflicts (data center located mid-level of a multistory building, in the interior of a building and other related constraints)

Air or Water Cooling - Potential Data Center Locations



Multistory



Interior of a Building

Step 2 – Climate Analysis

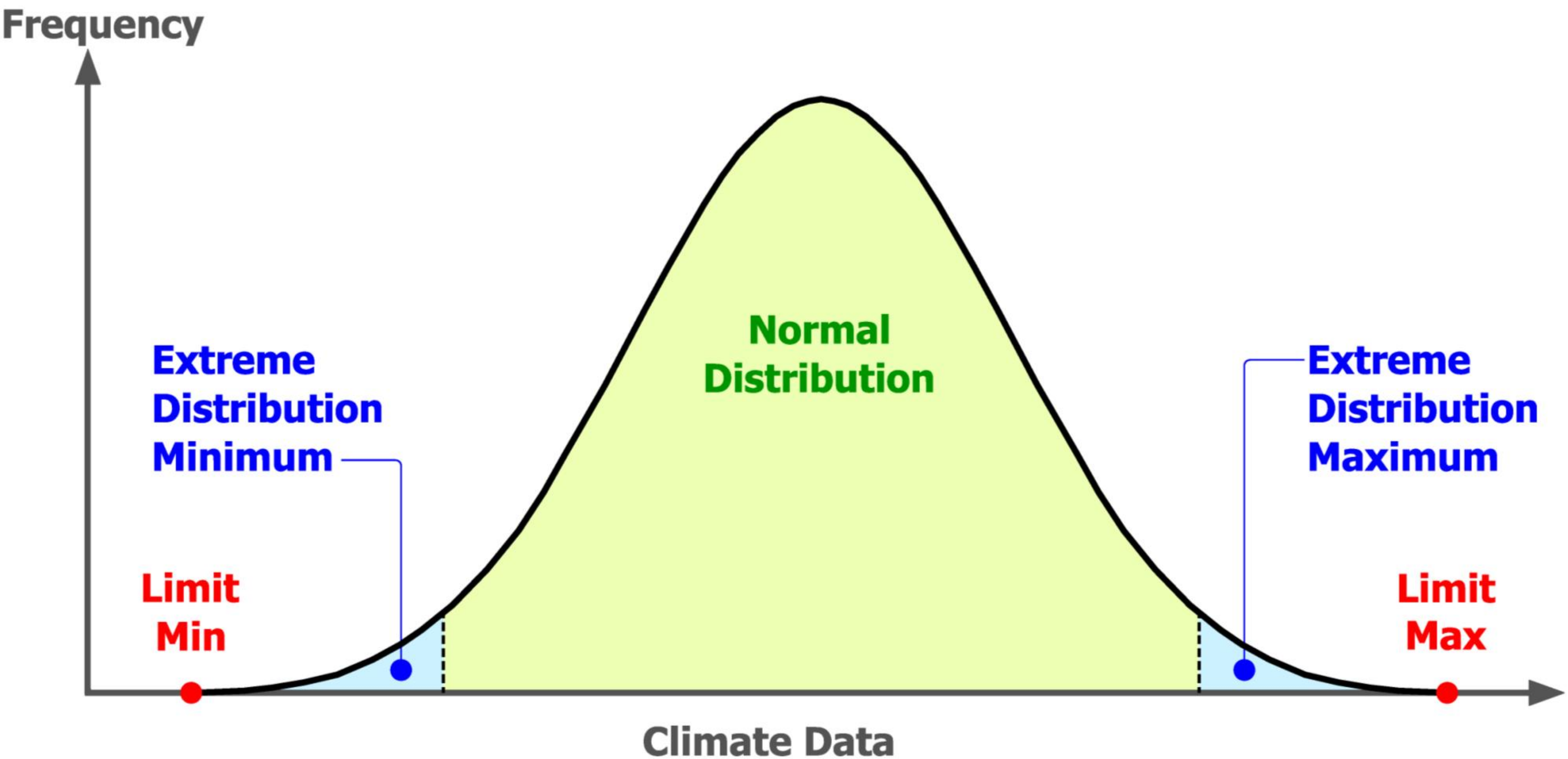
What climate data should be gathered?

- Boundary (lifetime) values. Minimums and maximums (temperature and humidity) that are never exceed.
- Historical, annual hourly observations (> 30 years of data)
- Extremes with statistical relevance

How should climate data be processed ?

- ASHRAE Climactic Design data
- Hourly analysis (bins)
- Joint frequency tables to correlate simultaneous events (DB, WB, dp, wind direction, solar, etc.)

Step 2 – Climate Analysis



Step 2 – Climate Analysis

Topic	Temperature Distribution					
	Limit		Extreme		Normal	
	Min	Max	Min	Max	Min	Max
Dry Bulb Temperature						
Wet Bulb Temperature						
Dew Point						

Step 3 – Air Quality Analysis

Topic	Description	Assessment		
		Below Average	Average	Above Average
Air Quality	Qualitative chemical analysis (smog, dust, dirt, etc.)			
	Contaminants (gas phase corrosive agents)			
	Wind and precipitation data			
Local / Regional Impacts	Topography and geography			
	Transportation patterns			
	Manufacturing plants			
	Construction activities			
	Seasonal effects (agriculture, pollen, wood burning, etc.)			


Dirt


Smoke


Products of Combustion


Pollen


Smog


Ozone


Forest Fire


Chemical Spill

Step 4 – High Level TCO (Total Cost of Ownership) Analysis

What constitutes a high level TCO analysis?

- Data gathering of investment parameters
- Payback computation (simple payback)
- Accepted metrics to validate results

What costs should be assessed?

- Capital / implementation costs
- Annualized Energy, Operations & Maintenance costs

What payback duration is acceptable?

- Refresh rate of 3 – 5 years for IT equipment in datacenter

Step 4 – High Level TCO Analysis

Topic	Baseline	Option 1	Option 2	Option 3
Capital Expenditure ($)				
Operating Expenditure ($ / Yr) E.g., Maintenance, Energy				
Simple Payback (Years)				

$$\textbf{Simple Payback (years)} = \frac{\textbf{Capital Expenditure}}{\textbf{Annual Operating Expenditure Savings}}$$

Can WATER be used to Cool IT Equipment?

Step 1 – Establish the Basics

Step 2 – Climate Analysis

Step 3 – Water Quality Analysis

Step 4 – High Level TCO Analysis

These steps can vary from professional judgment to in-depth analysis

Step 1 – Establish the Basics

Can water be used to cool your IT equipment?

- Varies based on configuration of cooling system and type of racks and equipment to be deployed.

What volume of water per minute, per day, per year is available to cool your IT equipment?

- Is it from a managed utility; if so, how much is available now & in the future?
- Are non-potable water sources available; if so, how much is available now & in the future?

Step 2 – Climate Analysis

What climate data should be gathered?

- Boundary (lifetime) values. Minimums and maximums (temperature, drought and utility company failures) that are never exceed.
- Historical infrastructure data, current capacities and future upgrade plans
- Seasonal variations in water temperature and availability with historical perspective

How should climate data be processed?

- Correlation of water temperatures with IT equipment cooling requirements
- Establish availability matrix for water sources


Chemical Contamination


Seasonal Effects


Drought


Service Interruptions

Step 3 – Water Quality Analysis

What water quality data should be gathered?

- Qualitative chemical analysis (pH, hardness, chlorides, iron, etc.)
- Contaminants (TSS, TDS, turbidity, PCB, etc.)

What local / regional environmental impacts should be assessed?

- Water source evaluation (well, reservoir, river or combination)
- Groundwater or surface water contamination sources
- Seasonal effects (droughts, service variations, etc.)

Step 3 – Water Quality Analysis

Topic	Description	Assessment		
		Below Average	Average	Above Average
Water Quality	Qualitative chemical analysis (pH, hardness, chlorides, iron, etc.)			
	Contaminants (TSS, TDS, turbidity, PCB, etc.)			
Local / Regional Impacts	Water source evaluation (well, reservoir, river or combination)			
	Groundwater or surface water contaminant sources			
	Seasonal effects (droughts, service variations, etc.)			

Step 4 – High Level TCO Analysis

Topic	Baseline	Option 1	Option 2	Option 3
Capital Expenditure ($)				
Maintenance Cost ($ / Yr)				
Energy Costs ($ / Yr)				
Simple Payback (Years)				

$$\textbf{Payback (years)} = \frac{\textbf{Operating Expenditure}}{\textbf{Capital Expenditure}}$$

Air or Water Cooling – Takeaways

Air or water can be used to cool the load directly or some portion of the cooling process such as the heat rejection from cooling equipment.

In order to understand energy savings potential:

- The maximum inlet temperature for YOUR IT equipment must be established
- A strategy regarding excursions must be established
- Need to understand the viability of air versus water cooling:
  - Resource, access or delivery concerns?
  - Climatic concerns (temperature, seasonal effects)
  - Quality (contaminants, pollution)
  - Conduct a high level TCO analysis
  - Conduct a risk analysis for each potential cooling medium

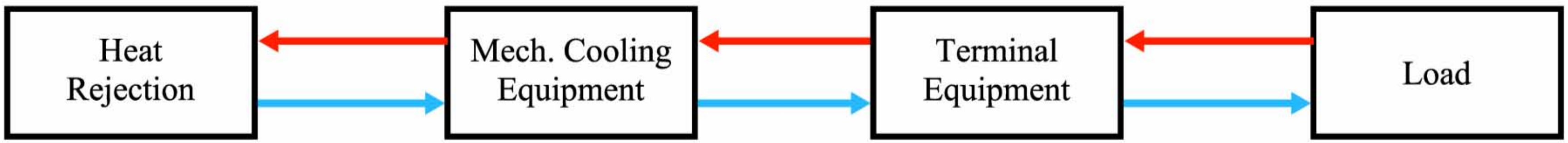
Cooling Systems – Overview

A cooling system removes the heat generated by the cooling load and rejects it to the outside environment. Cooling systems typically include the following components:

- **Terminal Unit**
  - Provides cool air to the load (e.g. air handling unit, CRAH).
- **Cooling Equipment**
  - Performs mechanical cooling using refrigeration (e.g. compressors)
- **Heat Rejection Equipment**
  - Rejects waste heat to the outdoor environment (e.g. drycooler)

Multiple components may be packaged within one piece of equipment

Cooling Systems – Overview



<table>
<tr><th>Heat Rejection</th><th>Mechanical Cooling Equipment</th><th>Terminal Equipment</th></tr>
<tr><td colspan="2">Chiller (Air-Cooled)</td><td>CRAH (Chilled Water)</td></tr>
<tr><td>Cooling Tower</td><td>Chiller (Water-Cooled)</td><td>CRAH (Chilled Water)</td></tr>
<tr><td>Condenser</td><td colspan="2">CRAC (DX)</td></tr>
<tr><td>Drycooler</td><td colspan="2">CRAC (Water / Glycol)</td></tr>
<tr><td colspan="2">Condensing Unit</td><td>Air Handler (DX)</td></tr>
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Cooling Equipment – Overview

The cooling equipment within a datacenter is often at partial load and operates 24 / 7, consequently selecting efficient equipment is critical:

- CRAC & CRAH Units
- Fans
- Pumps
- Chillers (air & water-cooled)
- Cooling towers, drycoolers & air-cooled condensers
- Humidifiers
- Outdoor air / ventilation equipment

Cooling Equipment – CRAC / CRAH

Computer room air handling (CRAH) units

- Contain a fan and chilled water cooling coil
- Typically installed in larger datacenters with a central cooling plant
- Reheat Components (can be electric, hot water, hot gas)
- Humidifiers (several types are available)

Computer room air conditioning (CRAC) units

- Contain a fan, DX cooling coil and a refrigerant compressor
- The compressor may be cooled by:
  - Water pumped through a cooling tower
  - Glycol pumped through a drycooler
  - Refrigerant routed through an air-cooled condenser

Rating of CRAH/CRAC units are covered by ANSI/ASHRAE Standard 127.

Cooling Equipment – Fans

HVAC fans account for 8% of total datacenter power consumption. Energy saving opportunities include:

REDUCE system pressure drop:

- Minimize supply and return air distribution system pressure drop.
- Low pressure drop filters & frequent filter maintenance

REDUCE air volume required for cooling by:

- Implementing variable flow / variable speed fans
- Maximizing cooling coil temperature change

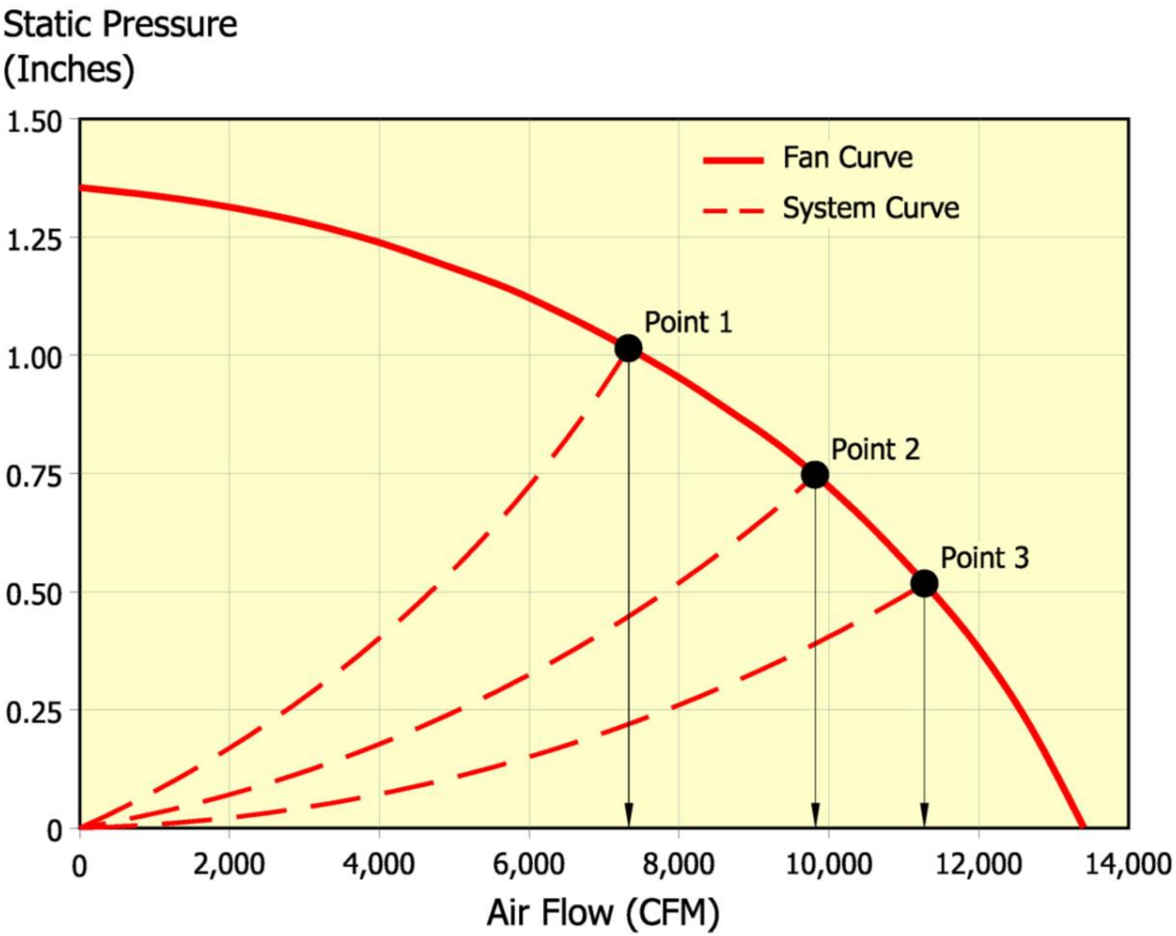
IMPROVE Equipment Efficiency

- Select fans with a high efficiency at expected operating conditions
- Use premium-efficiency or electrically-commutated motors

Cooling Equipment – Fan Curve Definitions

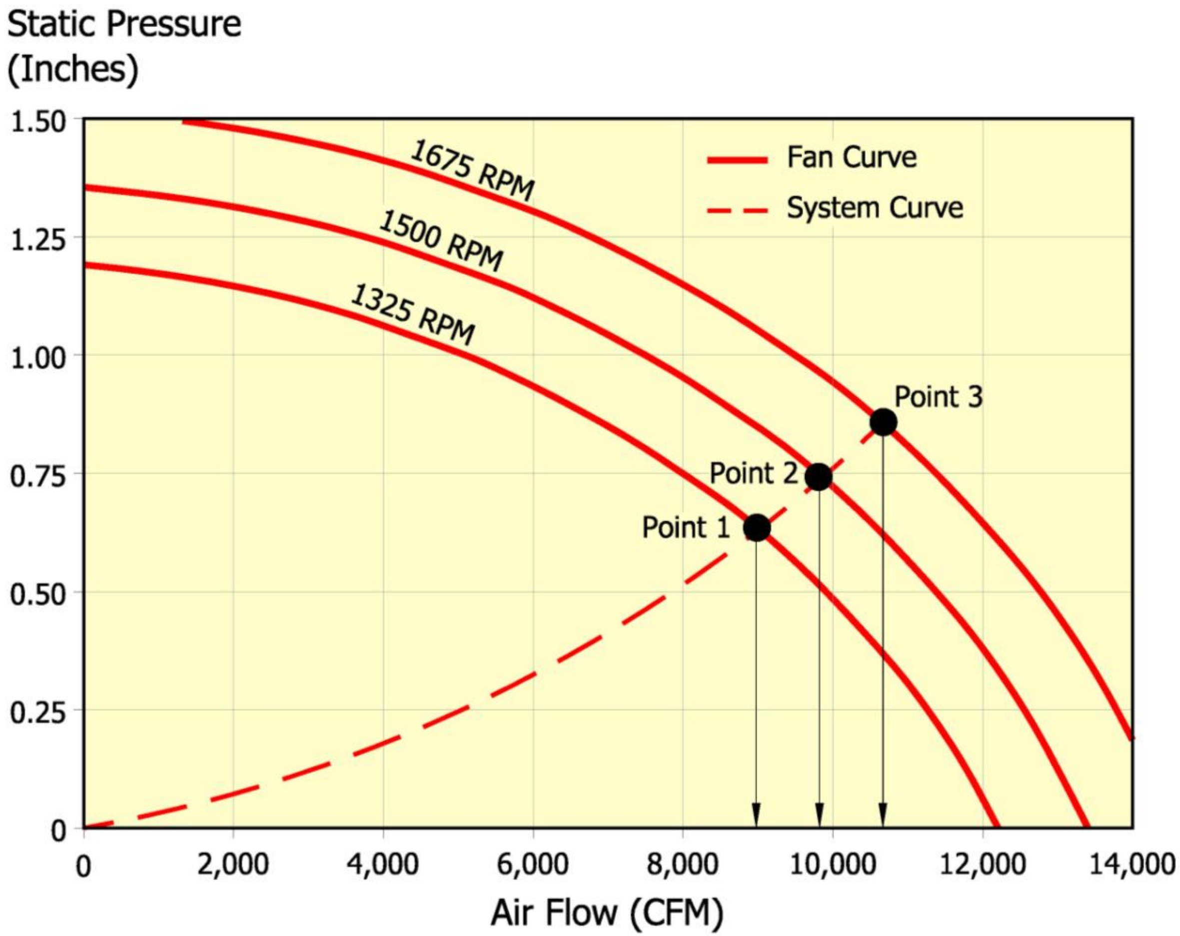
- **Fan Curve**
  - Plots the performance of a fan at a given speed.
- **Fan Curve Families**
  - Plots the performance of a fan at a varying speeds.
- **System Curve**
  - Plots the performance of a system.
  - System friction loss increases with increasing air flow quantity.
  - System friction loss is influenced by the physical dimensions and configuration of the air path (including filters, air outlets, etc.).
- **System Operating Point**
  - Intersection of Fan Curve and of System Curve.

Cooling Equipment – Fan Curve



Point	Static Pressure	Air Flow
1	1.02 Inches	7,300 CFM
2	0.75 Inches	9,800 CFM
3	0.52 Inches	11,300 CFM

Cooling Equipment – Fan Curve



Point	Speed	Air Flow
1	1,325 RPM	8,900 CFM
2	1,500 RPM	9,800 CFM
3	1,675 RPM	10,700 CFM

Cooling Equipment – Fan Laws

Fan Capacity: Air Flow (CFM) is proportional to Speed (RPM) of Fan

Fan Power: Power (HP) is proportional to [Speed (RPM) of Fan]^3

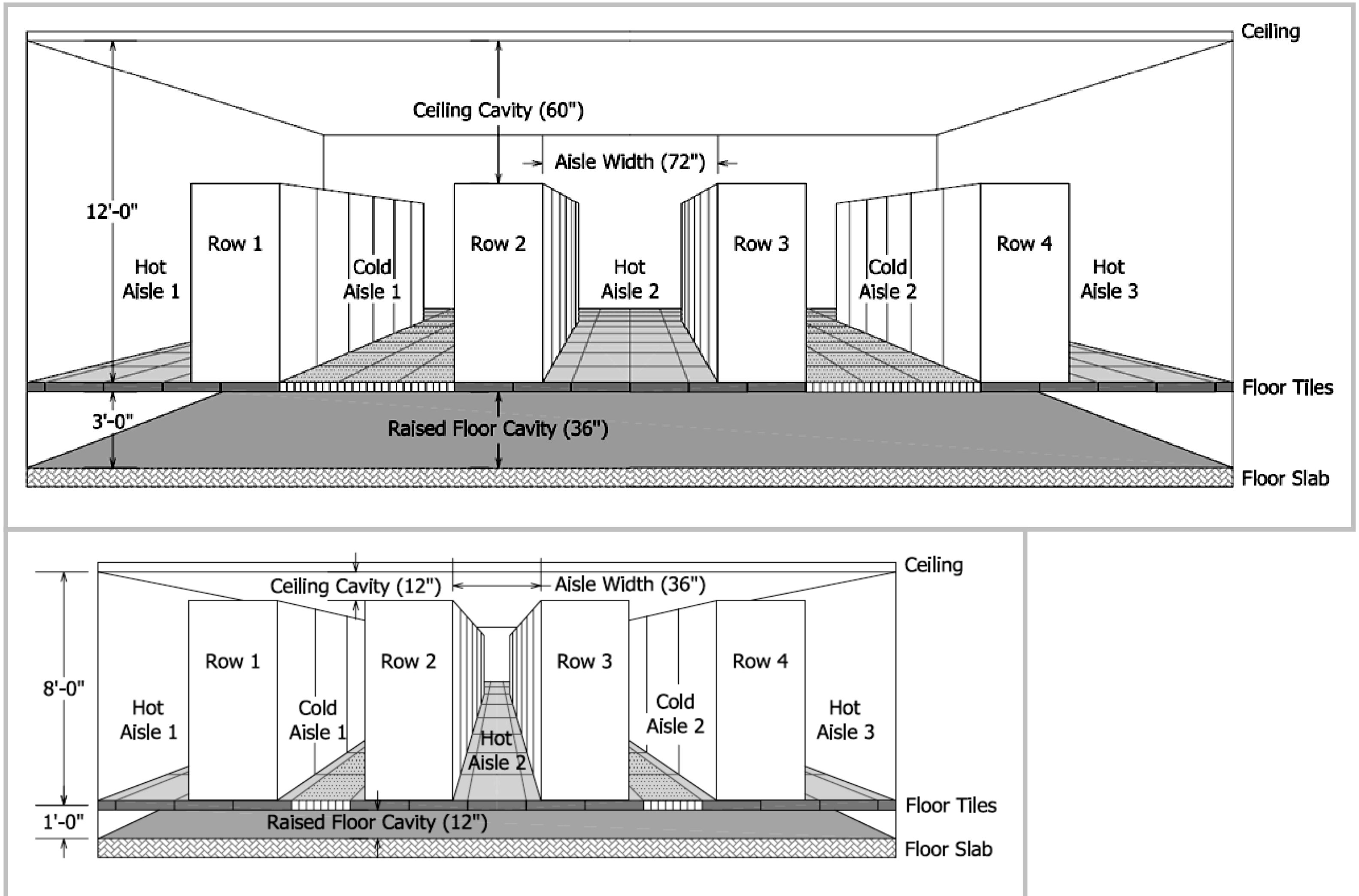
Fan Power at Varying Air Flow						
Air Flow	100%	90%	80%	70%	60%	50%
Fan Speed	100%	90%	80%	70%	60%	50%
Fan Power	100%	73%	51%	34%	22%	13%

Varying the Fan Speed to match the required Air Flow can provide a SIGNIFICANT reduction in power consumption during PART LOAD conditions

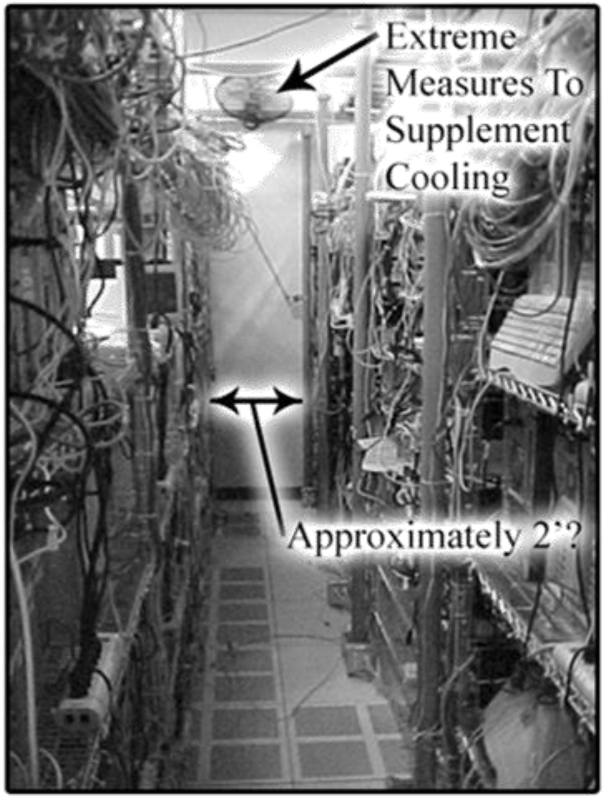
Show & Tell

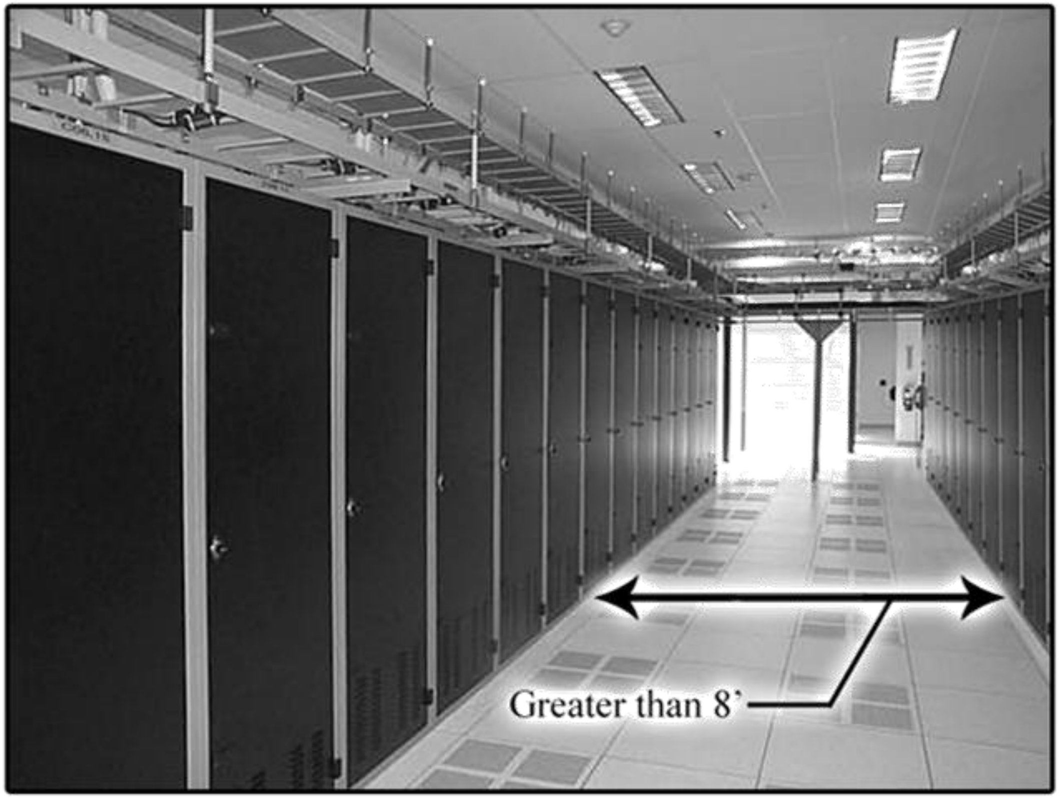
Video - 2

Cooling Equipment – Spatial Impact on Fan Pressure Drop



Cooling Equipment – Spatial Impact on Fan Pressure Drop





Aisle Width & Obstruction Comparison

Cooling Equipment – Pumps

Some energy efficiency opportunities include:

- The pump selection should be optimized for the operating point.
- The delta T of the chilled water should be optimized.
  - A greater delta T will result in lower flow & lower pumping energy consumption, but may result in lower chiller efficiency
- Utilize premium-efficiency motors & variable speed drives
- Various water distribution schemes should be considered, such as variable-speed primary pumping
- Optimize pipe sizes, equipment pressure drops, percentage of glycol

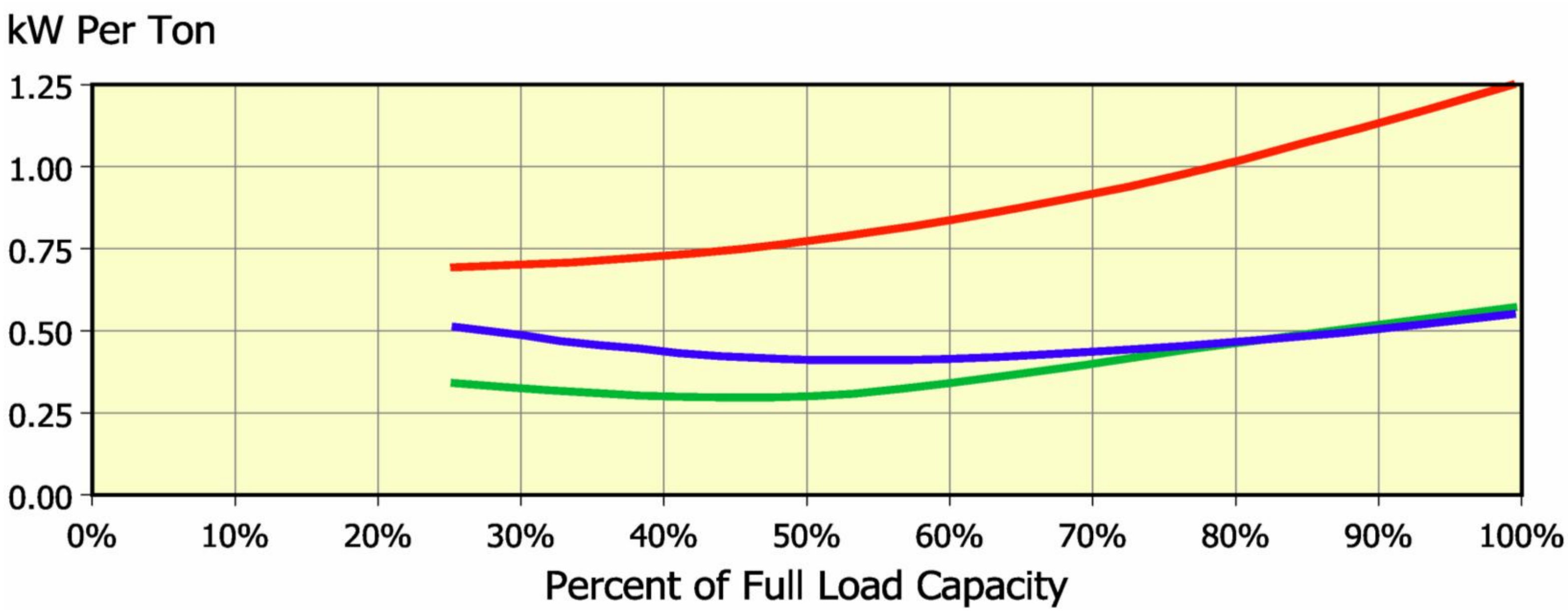
Cooling Equipment – Chillers

Parameters that impact chiller efficiency include:

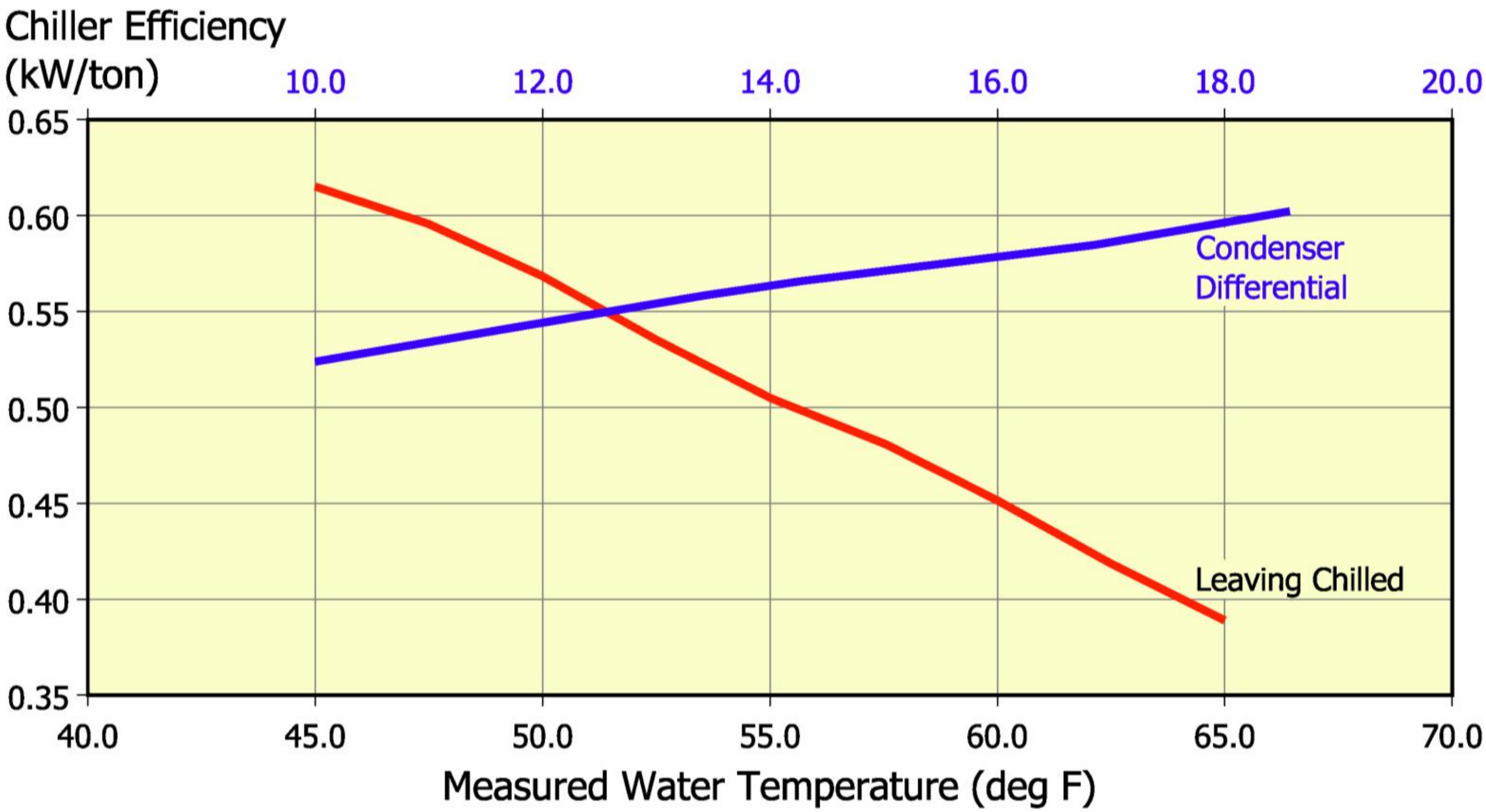
- Type and size of chiller bundles
- Compressor & drive optimization
- Refrigerant – cooled compressor motor
- Chilled water supply temperature
- Chilled water differential temperature (reduced pumping)
- Entering condenser water temperature
- Condenser water differential temperature
- Part-load efficiency as a function of compressor VFD drive

Cooling Equipment – Chiller Sizing & Selection

Chiller	Compressor kW / ton			
	25%	50%	75%	100%
400 Ton Air Cooled	0.69	0.77	0.96	1.25
1200 Ton Water Cooled w/o VFD	0.51	0.41	0.45	0.55
1200 Ton Water Cooled with a VFD	0.34	0.30	0.43	0.57



Cooling Equipment – Water-Cooled Chillers



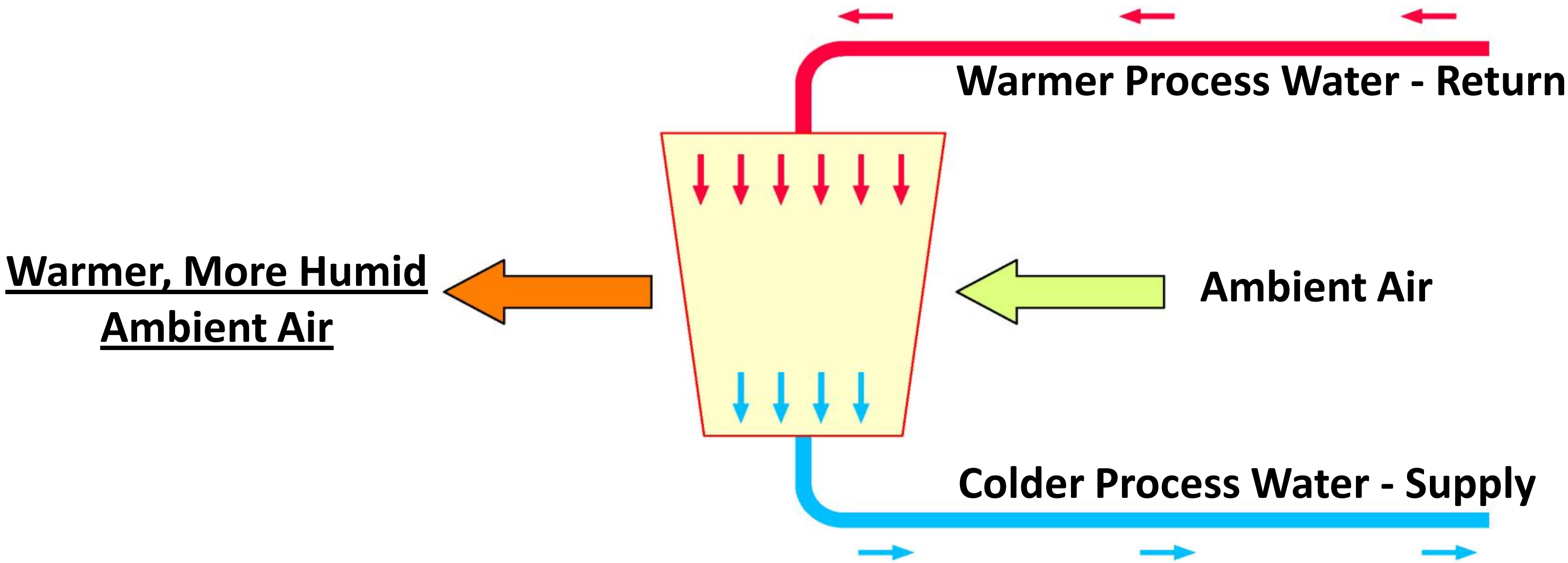
Sample Chiller Efficiency as a Function of Water Temperature
(with all other parameters held essentially constant)

Cooling Equipment – Water-Cooled Chillers

Considerations in the optimization of chiller energy efficiency

- Efficiency can increase dramatically if the differential temperature between the chilled water and the condenser water is lowered.
- If chilled water differential temperature is increased, pumping costs will be reduced with negligible effect on chiller energy consumption.
- Chiller efficiency decreases as the condenser water differential temperature increases.
  - Increasing the differential temperature to achieve reduced pump energy will clearly result in a less efficient chiller.
- Water-cooled chillers are more efficient than air-cooled chillers
- Use chillers with VFDs in lieu of multi-stage or inlet vane units

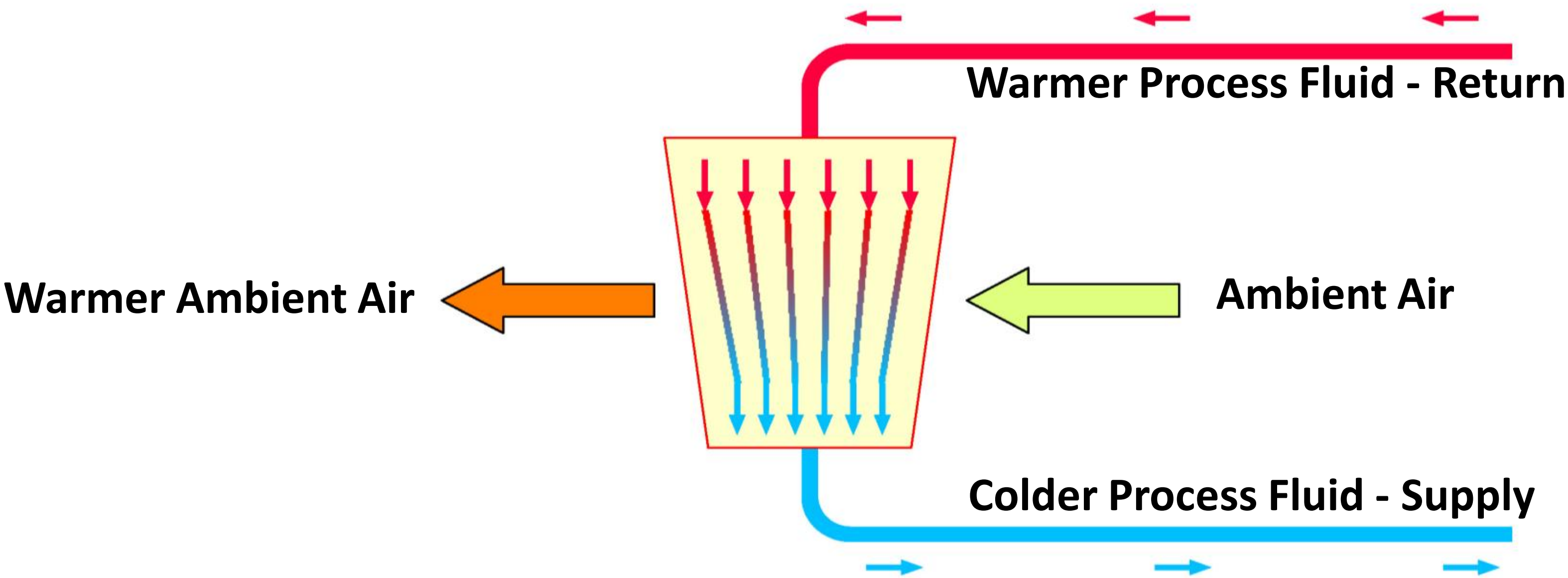
Cooling Equipment – Cooling Tower (Evaporative)



Considerations in the optimization of cooling tower energy efficiency

- Larger capacity tower allows approach temperature (difference between wet bulb and Colder Process Water - Supply) to be reduced
- Variable speed fans and energy efficient motors

Cooling Equipment – Drycooler (Sensible)

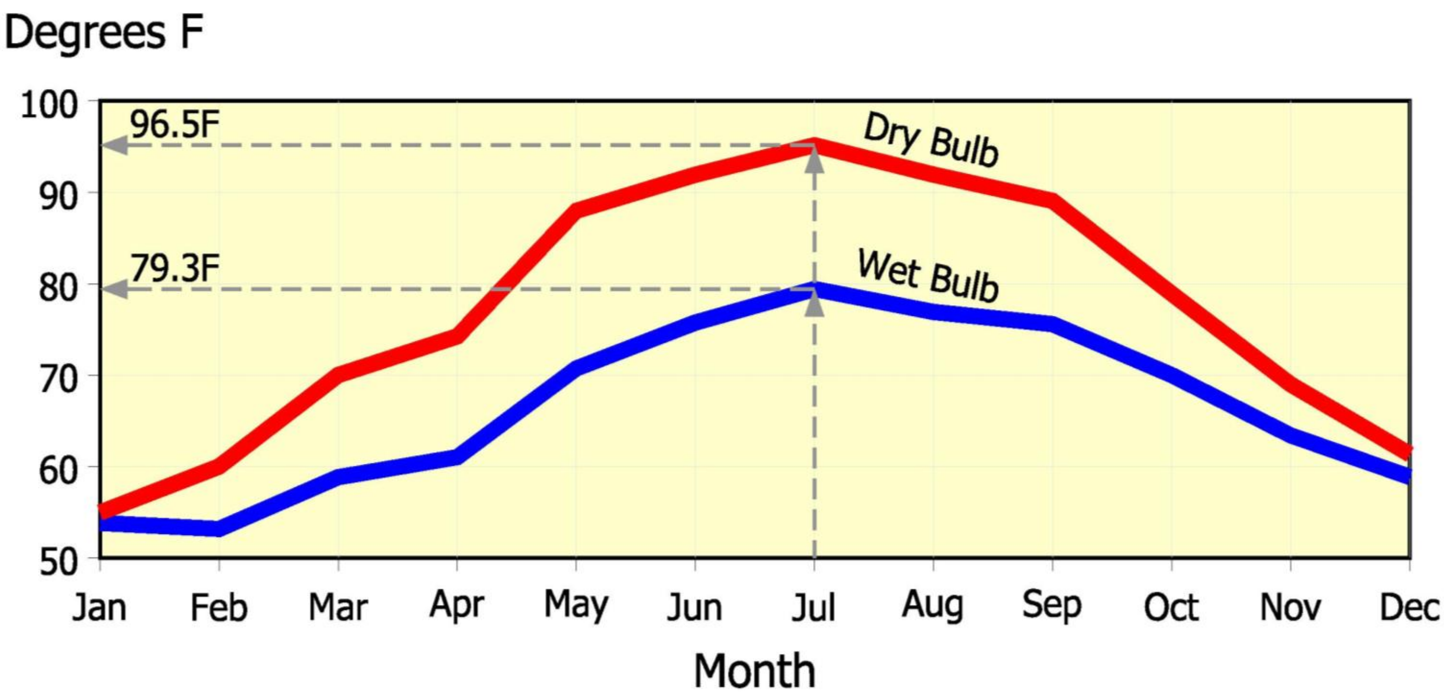


Considerations in the optimization of dry cooler efficiency:

- Larger coil to fan size ratios will increase energy efficiency
- Variable speed fans and energy efficient motors
- Some drycoolers include evaporative spray cooling

Cooling Equipment – Heat Rejection Comparison

Potential economizer hours are typically higher in condenser water systems utilizing evaporative cooling (wet bulb dependent) for heat rejection



Cooling Equipment – Humidification

High relative humidity may cause problems to datacom equipment (e.g. hydroscopic dust failures, tape media failures, corrosion).

Low relative humidity increases the magnitude and propensity for electrostatic discharge (ESD) , which can damage equipment.

The choice of which humidification technology to use is typically based on:

- Water quality (conductivity)
- System ease of maintenance
- Energy efficiency
- Quantity of humidification required

Humidifier Options:

- Infrared, Steam Generation, Ultrasonic

Cooling Equipment – Ventilation Air System

The occupancy level (number of people) in a datacenter is typically low, however, some ventilation air is mandated by code.

It is recommended that the outside air be conditioned so that it does not negatively impact the server area cooling system.

Dedicated outdoor air systems may be used to dehumidify the server space enabling the CRAH / CRAC units cool only sensible heat loads and therefore operate more efficiently.

Ventilation air must be adequately filtered

Air may be used to pressurize the server space to minimize gaseous and particulate contamination.

Cooling Equipment – Filters

Any outdoor air brought into a datacenter must be filtered to remove contaminants.

- Filter selection must consider the pollutants anticipated and capture efficiency of the media

ASHRAE 52.2 standardizes Minimum-Efficiency Reporting Values (MERV)

Dirty filters increase the total static pressure of an air distribution system when compared to its design point. This translates into more fan power, or reduced airflow and / or reduced sensible cooling capacity.

Pre filtration, or the installation of increasing levels of MERV particle efficiency, helps improve system efficiencies from both energy and operations perspectives.

Cooling Equipment – MERV Rating Chart

Based on ASHRAE Standard 52.5

MERV Rating	Dust Spot Efficiency	Arrestance	Typical Controlled Contaminant Picometer (pm) = $1x10^{-12}$ meters	Typical Applications & Limitations
17 to 20	**N/A**	**N/A**	**All Combustion Smoke < 0.30 pm Particle Size**	**Cleanrooms**
13 to 16	**89 - >95%**	**>98%**	**Proplet Nuceli (Sneeze) 0.3 - 0.1 pm Particle Size**	**Surgery Superior Comm. Bldgs**
9 to 12	**40 – 75%**	**90 - >95%**	**Welding Fumes 1 to 3 pm Particle Size**	**Superior Residential Hospital Laboratories**
5 to 8	**<20 to 35%**	**85 - >90%**	**Cement Dust 3 – 10 pm Particle Size**	**Standard Industrial / Commercial Buildings**
1 to 4	**<20%**	**<65 – 80%**	**Carpet Fibers / Pollen >10 pm Particle Size**	**Minimal Filtration**

Cooling Systems and Equipment – Takeaways

Select equipment and systems that operate efficiently at part load.

Use load matching techniques such as variable speed drives and variable capacity compressors (or turning equipment OFF).

A central plant is typically more efficient than a distributed system.

Investigate strategies to minimize chiller energy consumption.

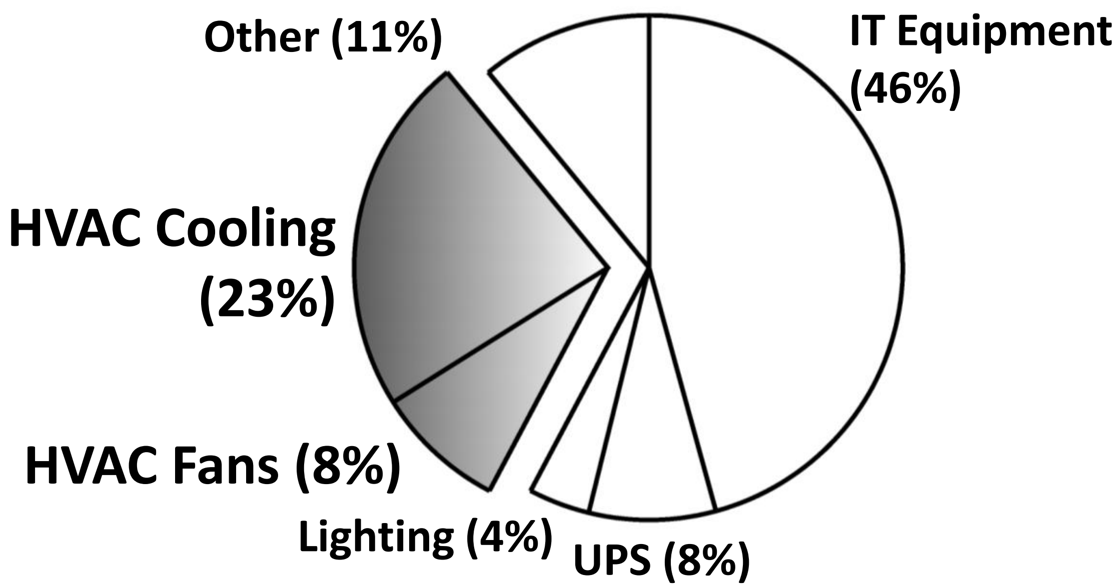
Consider over sizing system piping to keep pressure drops low.

Cooling towers are almost always more efficient than drycoolers (but require a water source; up to 25,000+ Gallons per day / MW load!)

Cooling Systems & Equipment – Takeaways

- A central plant is typically more efficient than a distributed system.
- Use variable water flow pumps whenever possible.
- Consider over sizing system piping to keep pressure drops low.
- Cooling towers are almost always more efficient than drycoolers (but require a water source)

Economizer Cycles – Overview



Typical Data Center Power Allocation

Avg. Power for Cooling

HVAC Cooling	23%
HVAC Fans	8%
TOTAL	31%

Using 100% Economizer

Energy Savings = 23 / 31

= 74%

Source: LBNL

Economizer Cycles – Overview

The Economizer Cycle, also called 'free cooling', REDUCES or ELIMINATES the need for mechanical (typically compressor-based) cooling

- Integrated economizers operate in conjunction with mechanical cooling and can modulate to provide partial cooling
- Non-integrated economizers are either fully ON or OFF (reduced energy savings compared to integrated)

Economizer types include:

- Air-side economizer (uses outdoor air for air cooling)
- Adiabatic air-side economizer (uses water spray for cooling supply air)
- Water-side economizer (use low outdoor temperature to cool water)
- Applicability depends on climate, codes, performance, and preference

Economizer Cycles – Overview

Data centers differ from office environments in:

- The need for humidity control
- Concerns about contamination from outdoor air sources
- The potential to provide higher supply air temperatures which can increase economizer cycle hours on an annual basis
- The cooling requirements of a data center translate to very significant airflow requirements
  - Large intake / relief openings for air-side economizers
- Reliability impact of changing between economizer cycle and mechanical cooling cycles
- 24 x 7 as opposed to 10 x 5 operation

Economizer Cycles – Overview

Comparison of Typical Air Temperatures (in Fahrenheit)			
Outside Air	Recommended Datacom Equipment Inlet Temperature		
	Pre-ASHRAE	ASHRAE	Revised ASHRAE
50 to 80.6	68 to 70	68 to 77	64.4 to 80.6

ASHRAE datacom standards enable INCREASED economizer usage

Economizer Cycles – Air-Side

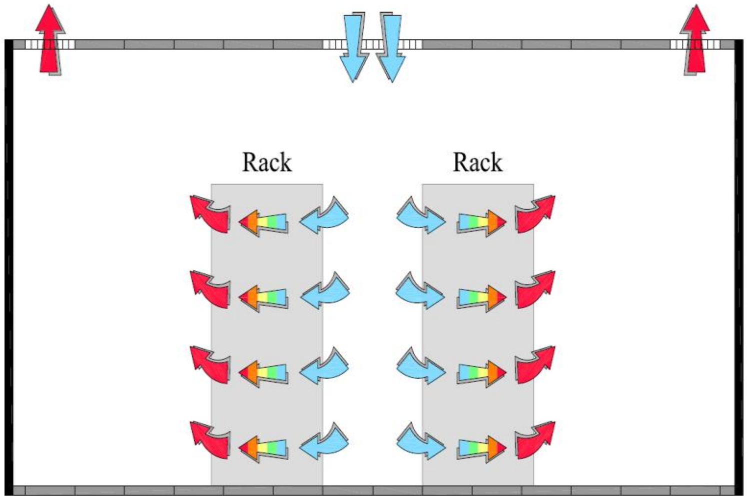
An air-side economizer utilizes outdoor air for cooling.

- Partial or full economizer mode is available when the outdoor dry bulb temperature is low enough.
- Dampers are used to adjust the mixture of outdoor air & return air
- Typically better suited for central air-handlers than CRAC units

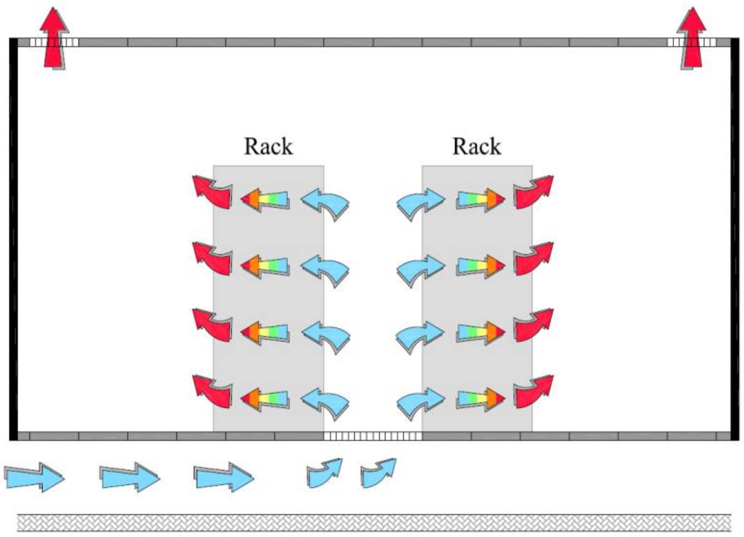
Economizer cycle is controlled using:

- Dry bulb temperature sensors (temperature control)
- Combination of temperature & humidity sensors (enthalpy control)

Economizer Cycles – Oversimplified Air-side Economizer

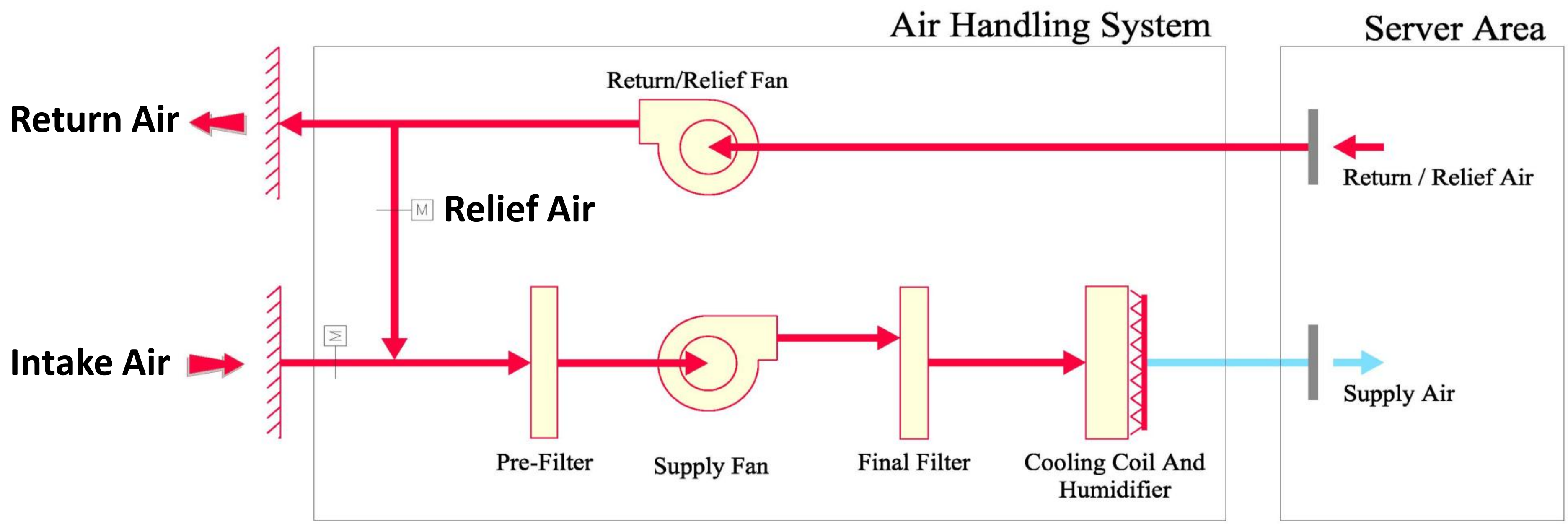


Overhead Air Supply



Raised Floor Air Supply

Economizer Cycles – Air-Side Economizer



Location	Economizer		
	None	Partial	Full
Intake Airflow	0 %	10 %	100 %
Exhaust / Relief Airflow	100 %	90 %	0 %
Return Airflow	0 %	10%	100 %

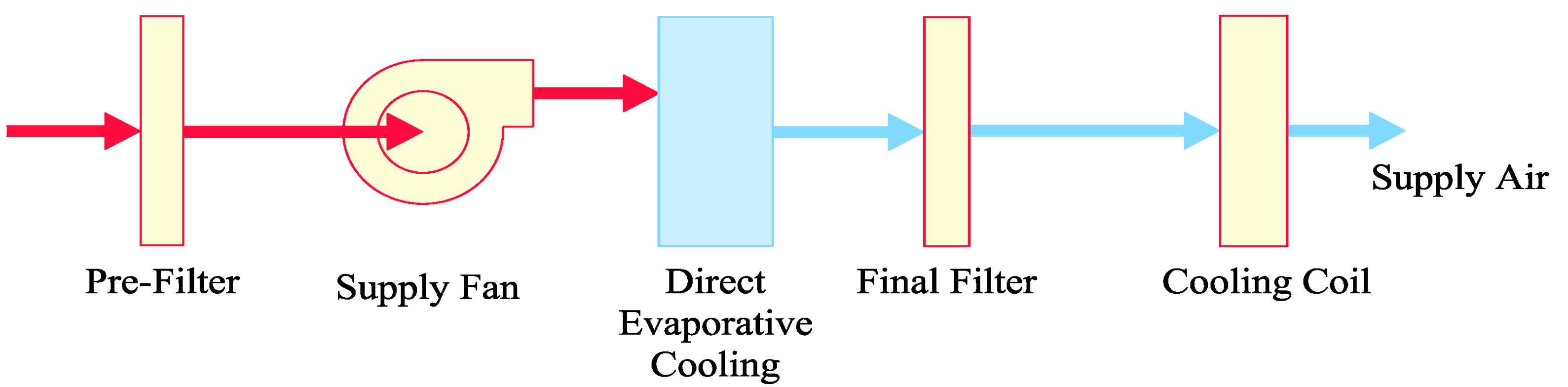
Economizer Cycles – Air-Side

Percentage of the Year Below Drybulb Weather Conditions				
Outdoor Air Drybulb °F (°C)	69 (21)	63 (17)	57 (14)	51 (11)
Supply Air Temp °F (°C)	70 (21)	64 (18)	58 (14)	52 (11)
Los Angeles	**86%**	**59%**	**32%**	**6%**
San Jose	**80%**	**64%**	**39%**	**18%**
Denver	**82%**	**72%**	**61%**	**51%**
Chicago	**80%**	**70%**	**62%**	**52%**
Boston	**83%**	**71%**	**61%**	**50%**
Atlanta	**65%**	**51%**	**41%**	**29%**
Seattle	**65%**	**51%**	**41%**	**29%**

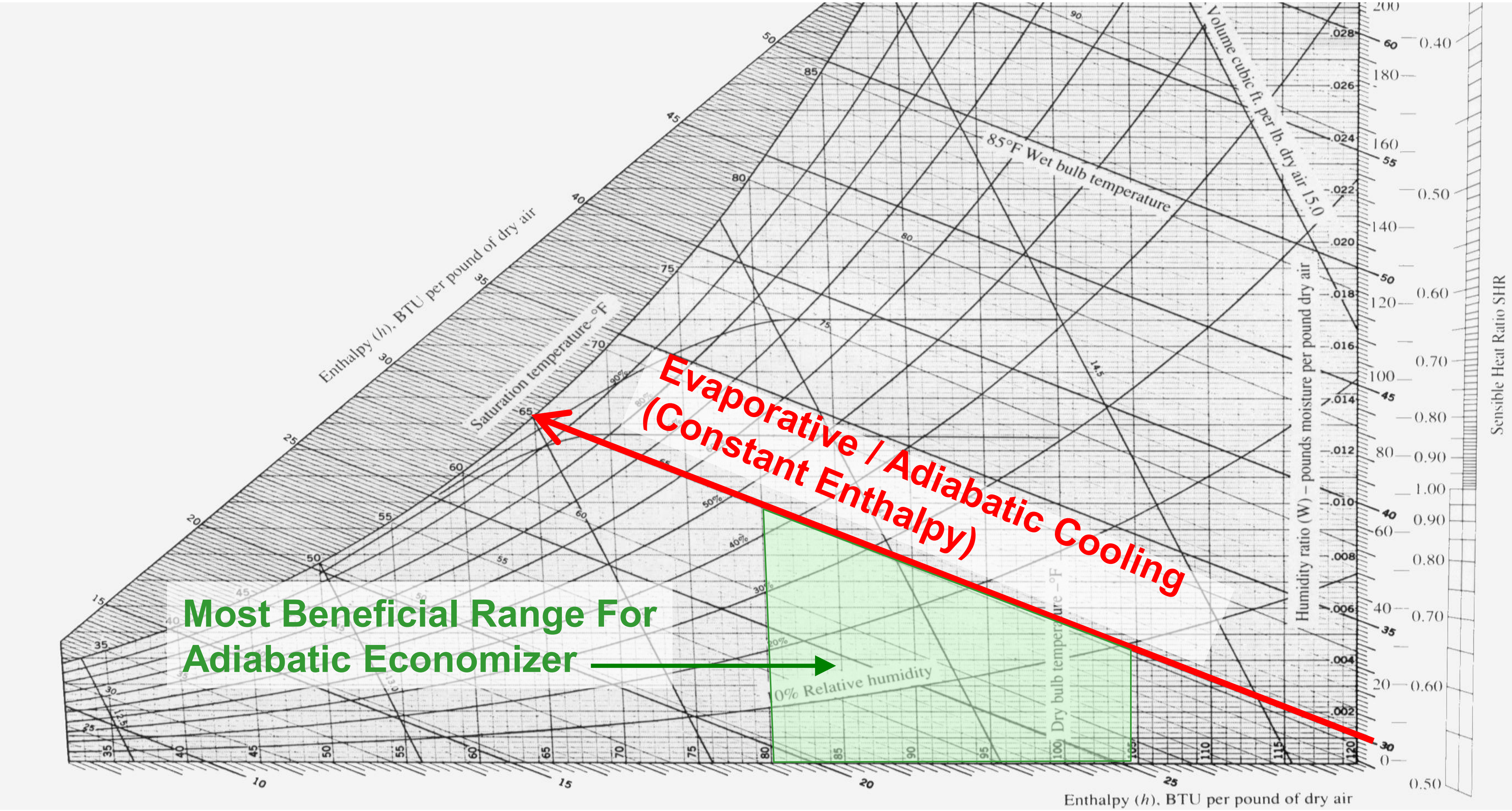
Economizer Cycles – Adiabatic Air-Side

Air passes through an evaporative cooling section and is humidified (direct addition of moisture) and pre-cooled by the evaporative / adiabatic process

- Extends hours of free cooling (especially for dry, hot climates)
- Improves air filtration (including gaseous contaminants)
- Increased fan power (due to additional pressure loss)
- Water source needed



Economizer Cycles – Adiabatic Air-Side



Economizer Cycles – Water-Side

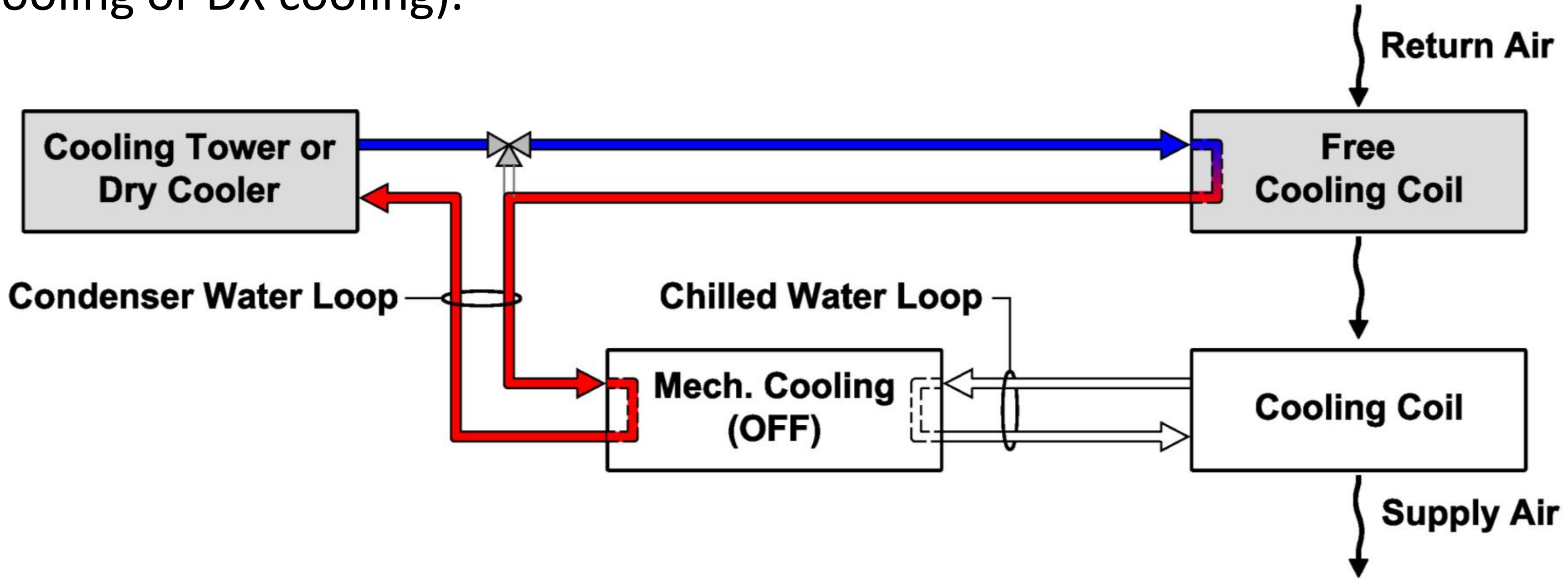
Water-side economizers use low outdoor temperatures to cool water & reduce the need for mechanical (compressor) cooling.

- Partial or full economizer mode when the outdoor wet bulb temperature is low enough.
- Requires motorized control valves to divert the direction of the water flow through the economizer.
- Two basic types of water-side economizers - direct and indirect.

Economizer Cycles – Water-Side (Direct)

In a direct system, condenser water is circulated directly through the cooling coil.

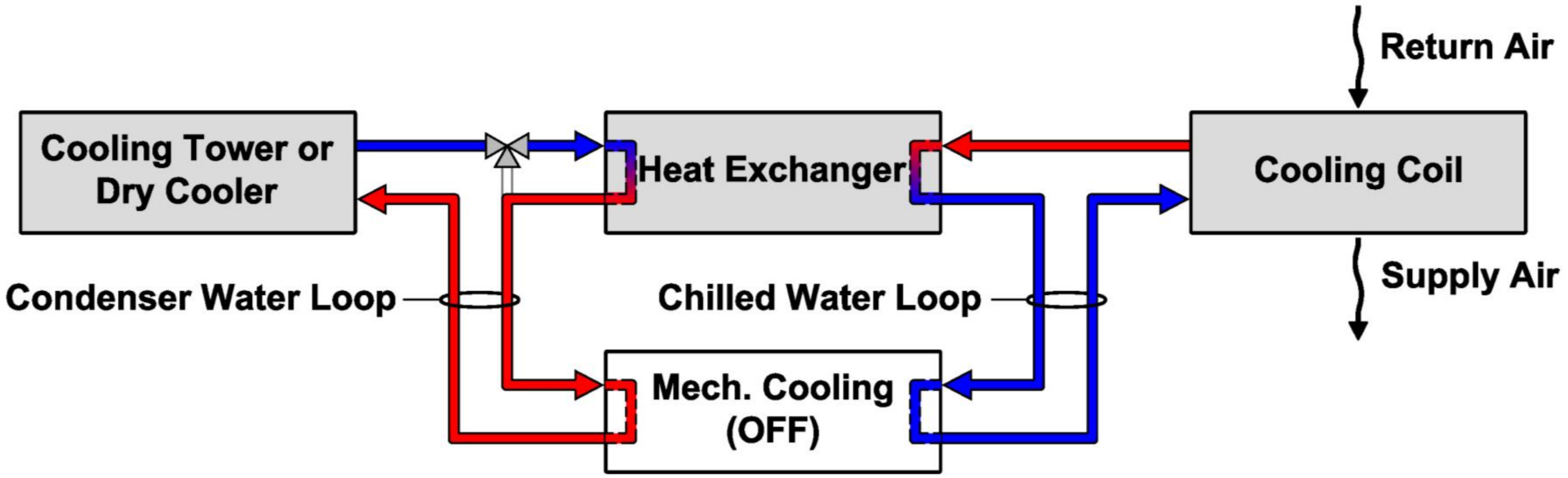
The most common direct water economizer system uses independent coils within the CRAC unit to allow cooling from either of two sources (free cooling or DX cooling).



Economizer Cycles – Water-Side (Indirect)

In an Indirect system, a heat exchanger is added to separate the condenser-water and chilled-water loops.

- Commonly used in conjunction with water-cooled chillers.
- Additional energy is used to pump water through the heat exchanger



Economizer Cycles – Water-Side

Percentage of the Year Below Wetbulb				
Outdoor Air Wetbulb °F (°C)	59 (15)	53 (12)	47 (8)	41 (5)
CWS °F (°C)	66 (19)	60 (16)	54 (12)	48 (9)
Supply Air Temp °F (°C)	70 (21)	64 (18)	58 (14)	52 (11)
Los Angeles	**68%**	**36%**	**13%**	**3%**
San Jose	**78%**	**46%**	**21%**	**6%**
Denver	**93%**	**77%**	**63%**	**51%**
Chicago	**75%**	**64%**	**55%**	**46%**
Boston	**75%**	**63%**	**52%**	**41%**
Atlanta	**56%**	**44%**	**33%**	**22%**
Seattle	**90%**	**68%**	**45%**	**21%**

Economizer Cycles - Takeaways

Economizer cycles provide an opportunity for substantial energy and cost savings in data centers

Raising the supply air set point in a facility can significantly increase the utilization of the economizer cycle

The potential energy savings of air-side, adiabatic air-side and water-side economizers are climate (and therefore location) dependent

Integrated economizer controls allow partial use of the economizer cycle and increase annualized utilization (true for all types of economizers)

Air Distribution – Overview

The objective of a datacenter air distribution system is to ensure that a sufficient quantity of cool air reaches the inlets of the datacom equipment.

- ASHRAE Environmental specifications define the quality
- Datacom equipment Thermal Reports define the quantity
- Level of conformance can be measured by the Rack Cooling Index (RCI)

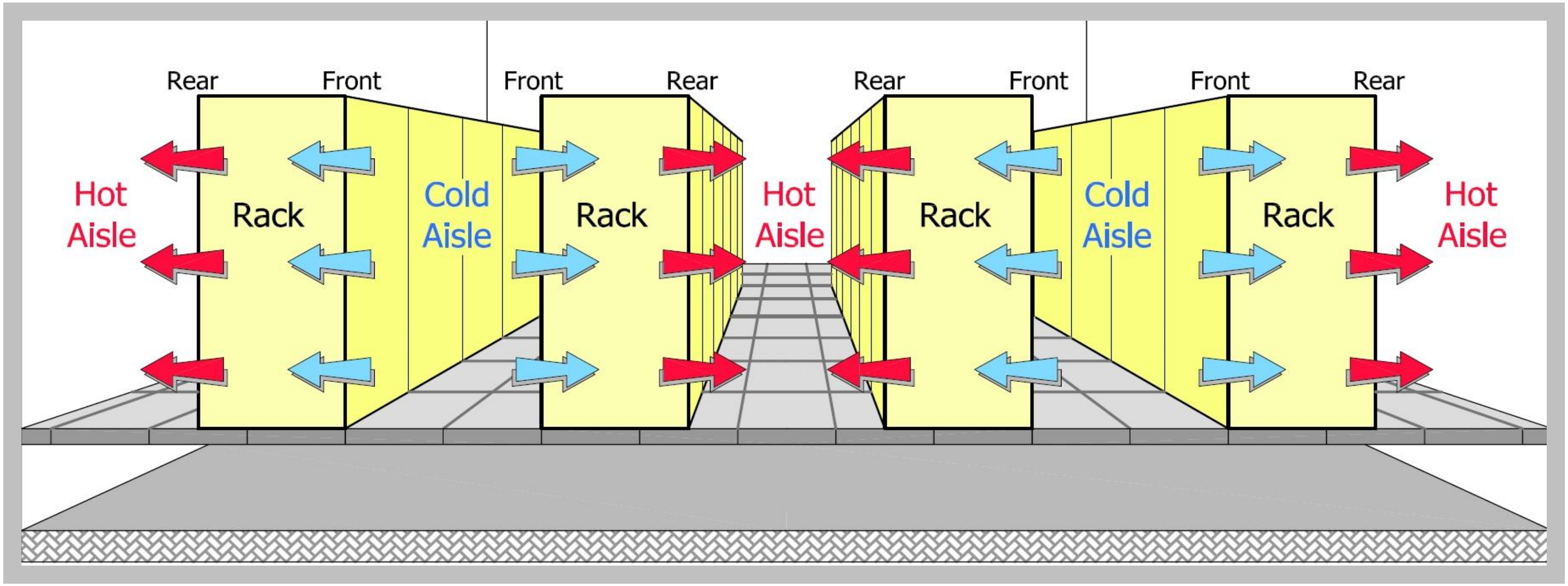
This objective is achieved most effectively & efficiently by:

- Deploying a Hot-Aisle / Cold-Aisle configuration
- Maintaining effective separation between supply air and return air flows
  - Supply cold air as close to the datacom equipment intakes as possible without prior mixing with ambient air
  - Return hot exhaust air without prior mixing with ambient air

Air Distribution – Hot-Aisle / Cold-Aisle Configuration

Datacom equipment deployed in rows with intakes facing the COLD AISLE

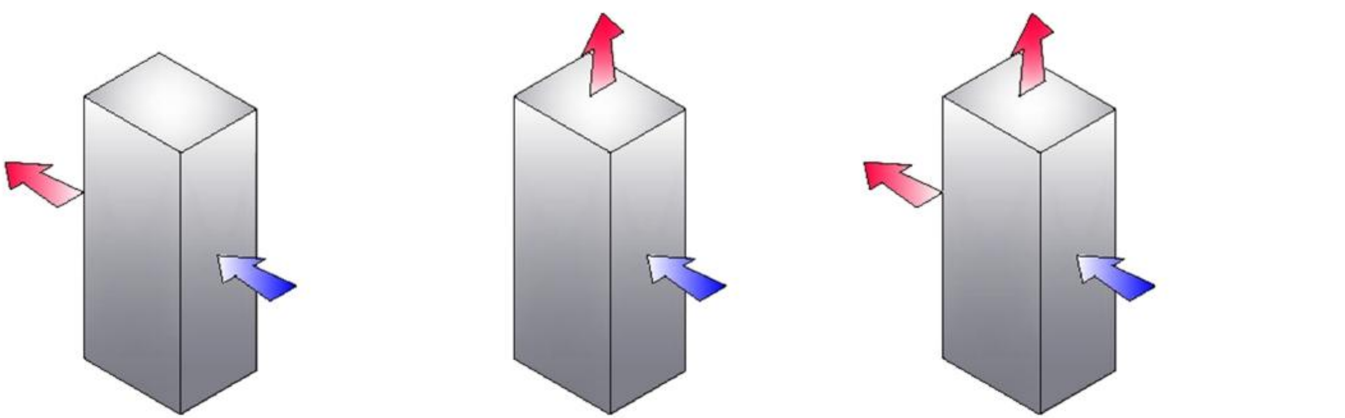
Cool air is supplied to the COLD AISLE, it then passes through the datacom equipment and is discharged into the HOT AISLE



Air Distribution – Rack Airflow Characteristics

Although there is considerable variation in the airflow characteristics of different datacom equipment, the following should be noted:

- Recommended rack air flow directions are F-R, F-T or F-T/R
- Racks may require an air flow quantity of 2000 to 3000 CFM
- Inlet conditions (temperature, humidity, etc.) are important to the reliable operation of the datacom equipment



Front to Rear (F-R)   Front to Top (F-T)   Front to Top and Rear (F-T/R)

Air Distribution – Systems

The air distribution systems most commonly used within datacenters include the following:

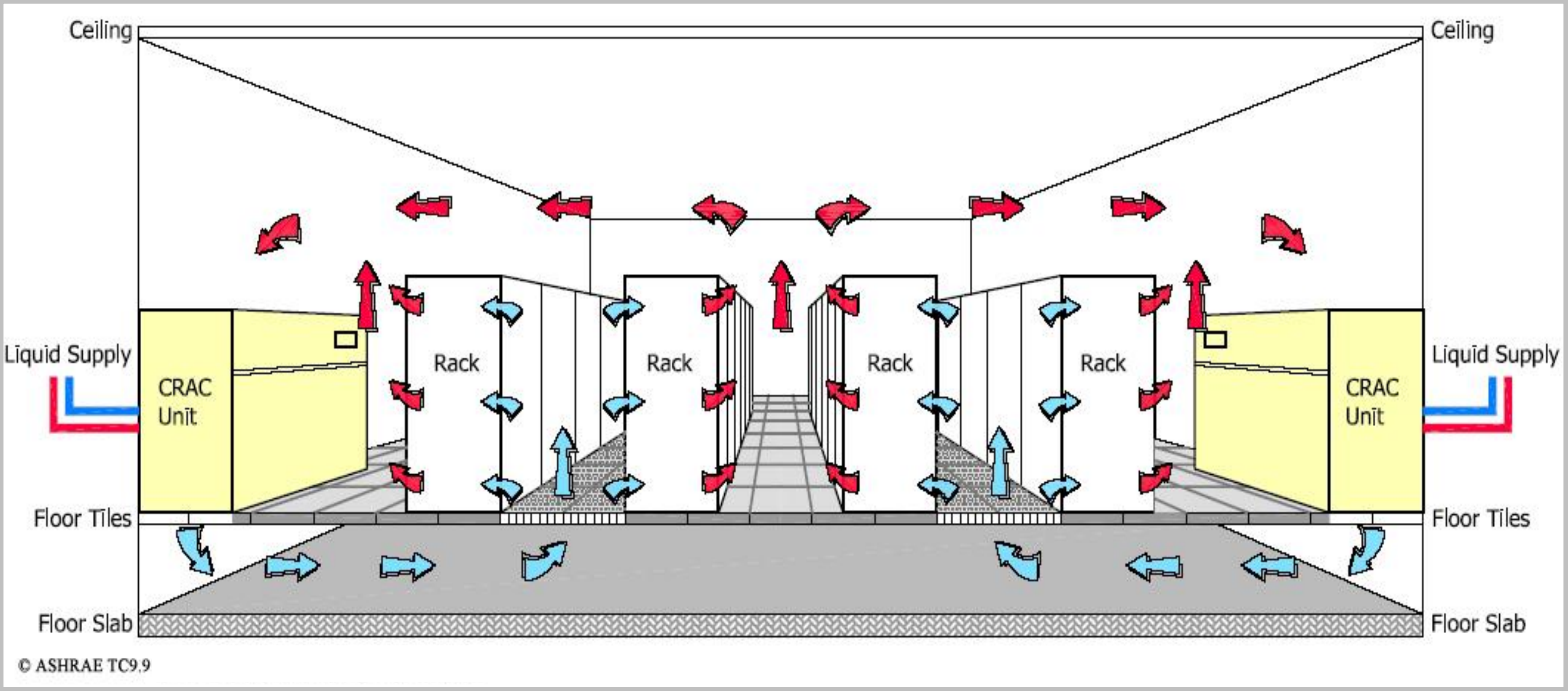
- Vertical Underfloor (VUF)
- Vertical Overhead (VOH)
- Local Distribution (typically used for supplemental cooling)

Each system has different advantages & disadvantages in the consideration of first cost, energy efficiency, flexibility / adaptability, etc.

Regardless of the distribution system selected, it should be configured to support the Hot-Aisle / Cold-Aisle protocol.

Air Distribution – Vertical Under Floor (VUF) System

Cooling airflow is supplied to the equipment racks through registers via an overhead ductwork system that is connected to air handlers.



Air Distribution – Vertical Overhead (VOH) System

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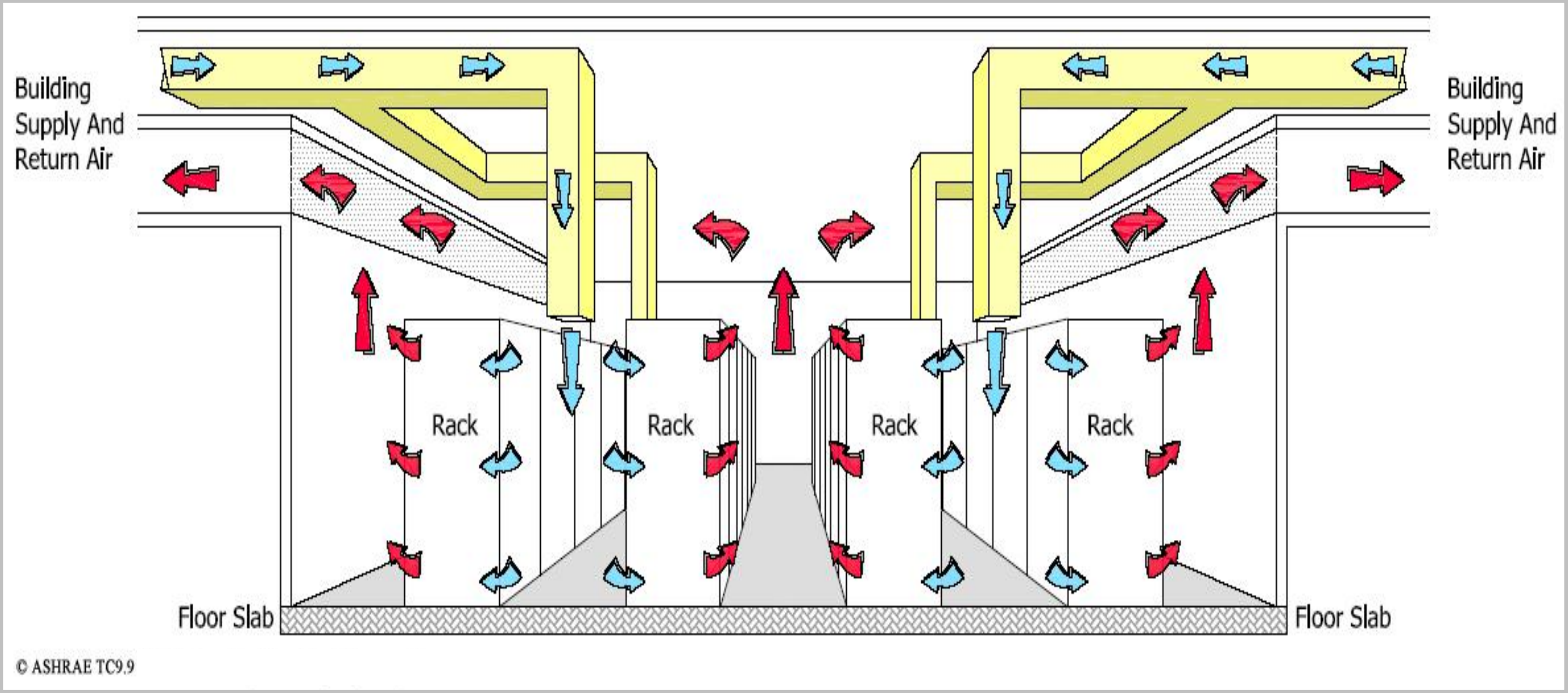


Air Distribution – Localized Cooling Systems

Localized cooling systems may be used if good airflow distribution cannot be achieved throughout the server area, or if there are high density loads. Some examples include:

Local Overhead Cooling units

- Cooling units placed over the cold aisles or over the servers.

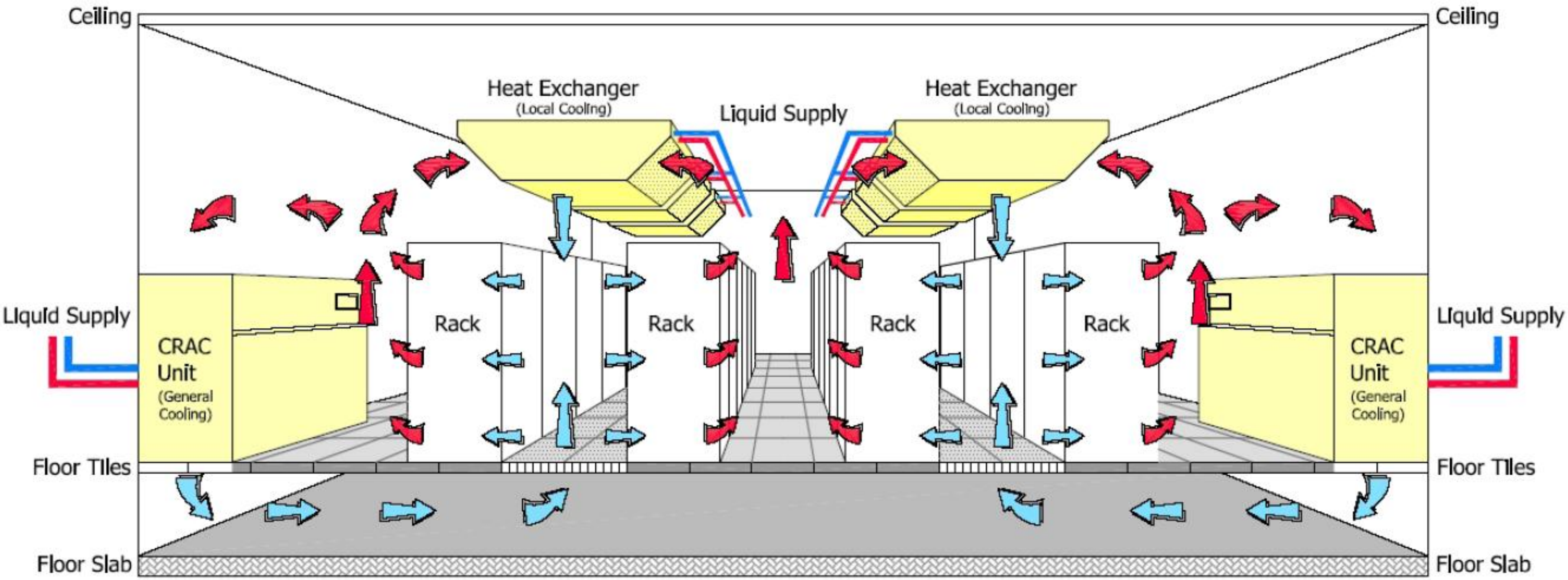
Rack-mounted heat exchangers

- Either cool the hot exhaust air from the rack, or sub-cool the supply air prior to entering the rack

Local In-Row Cooling units

- Cooling units placed directly in the rows of servers.

Air Distribution – Local Overhead Cooling Units

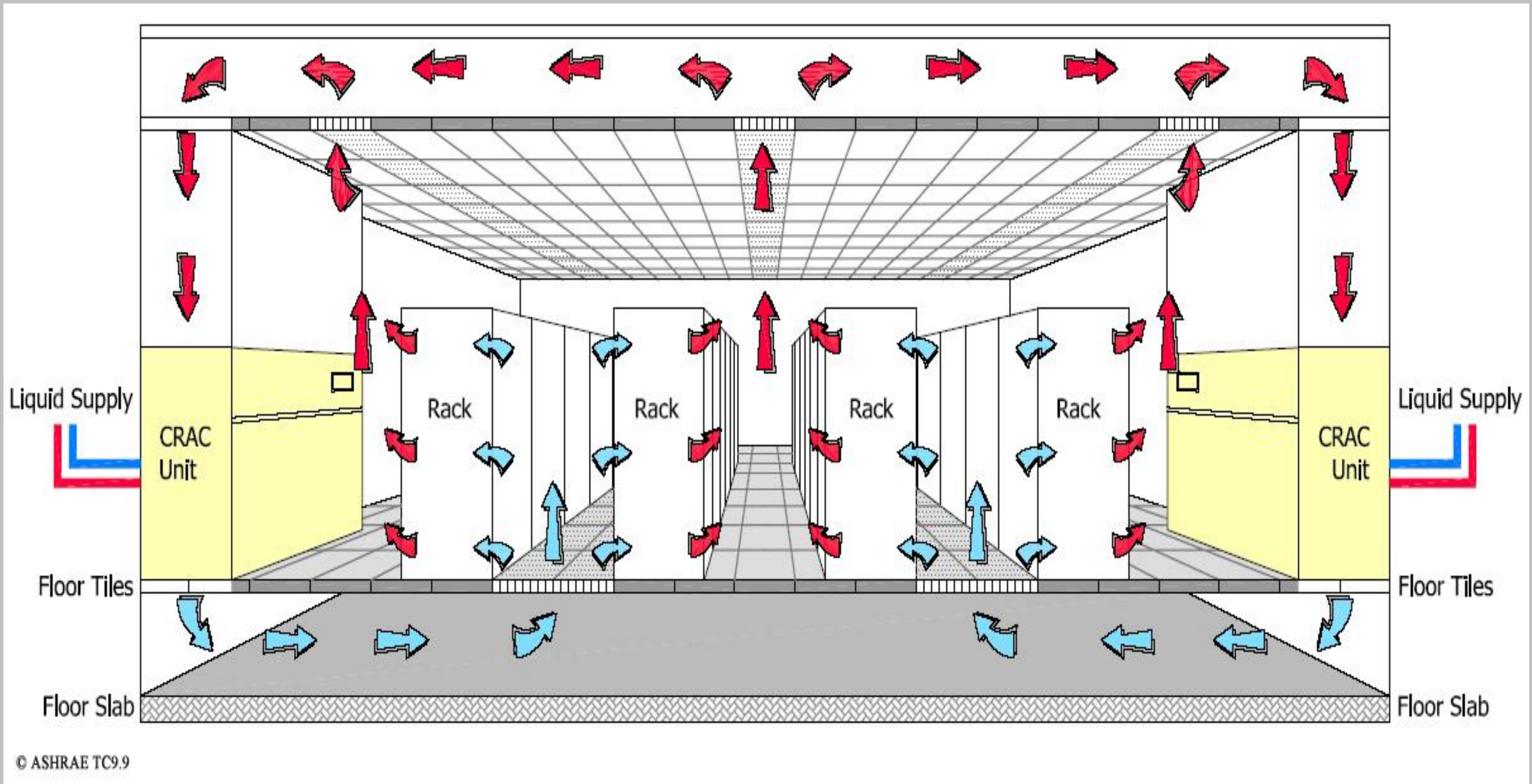


Air Distribution – Improvements

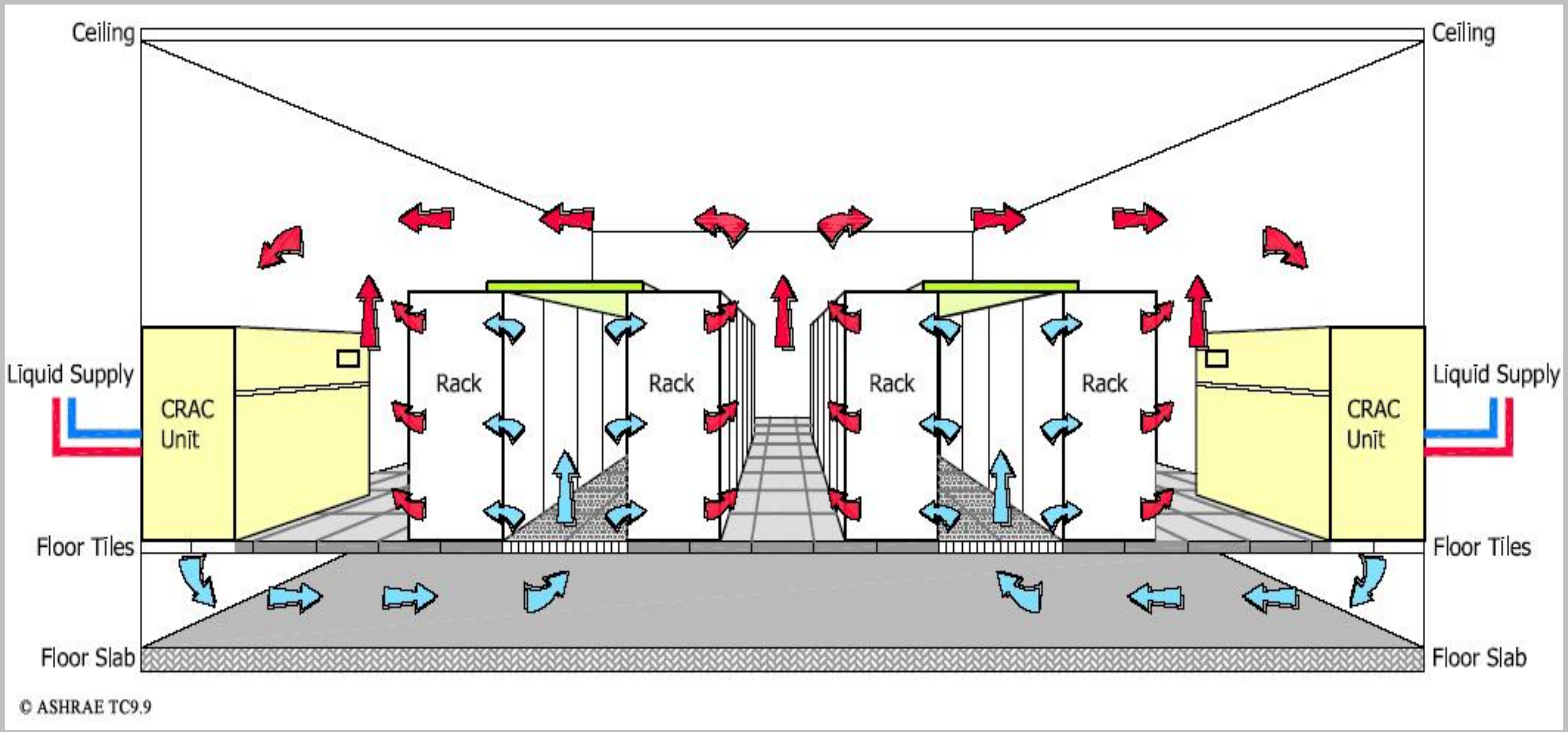
In addition to using the hot-aisle / cold-aisle configuration, the following techniques may be employed to enhance airstream separation and minimize recirculation:

- Prevent recirculation of hot air by installing blanking panels at all open rack locations and within racks
- Use return air plenums and duct the returns of cooling units to draw the warmest air from the top of the space.
- Install airflow barriers such as hot aisle / cold aisle containment to reduce mixing of hot exhaust air with cooler room air
- Locate CRAC units at the end of the hot aisle to shorten the path for return air and reduce direct short-circuiting of cold air from cold aisles.

Air Distribution – Return Air Plenum

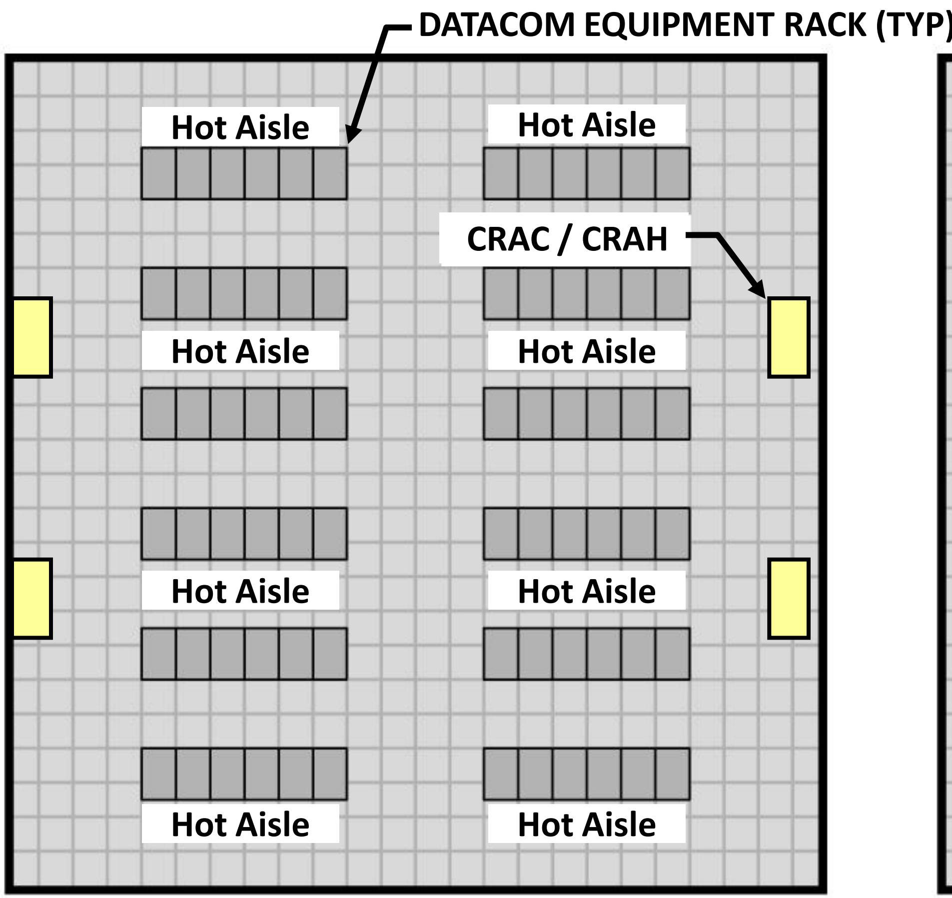


Air Distribution – Cold Aisle Containment

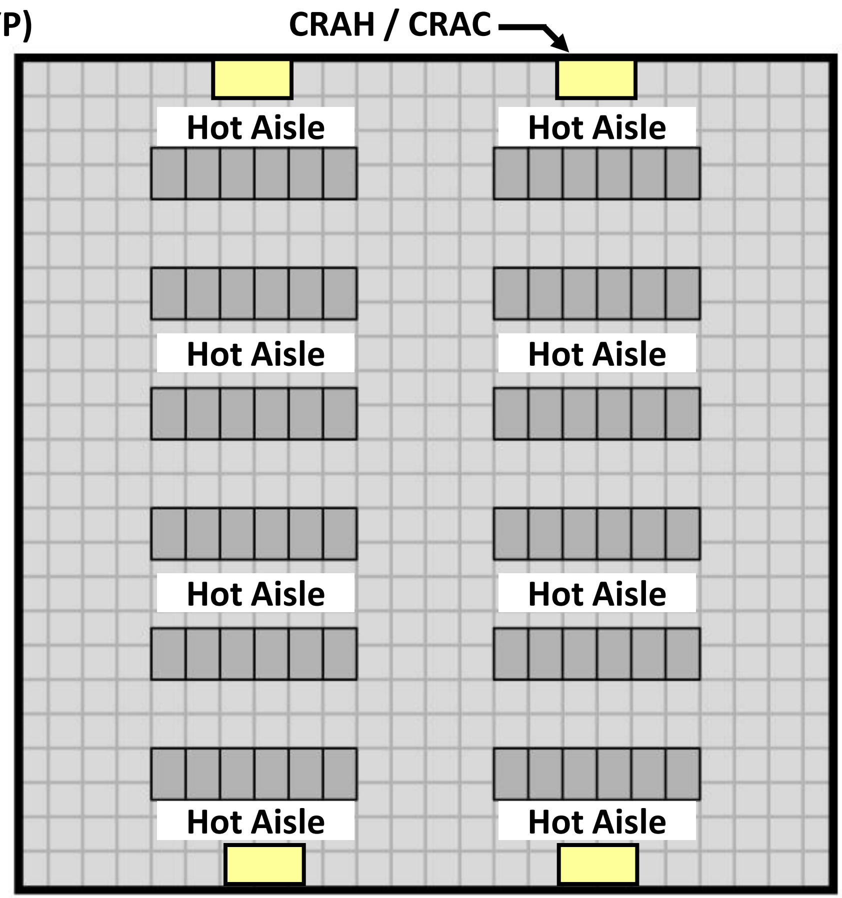


LBNL Cold Aisle Containment study achieved fan energy savings of ~ 75%

Air Distribution – CRAC Unit Arrangement



RECOMMENDED CRAC Arrangement



Less Efficient CRAC Arrangement

Air Distribution – Improvement Examples

Return air duct on top of CRAC unit connects to the return air plenum.

Duct on top of each rack connects to the return air plenum.

Air Distribution – Takeaways

Different distribution systems (overhead, underfloor, local) are available

Use a hot-aisle / cold-aisle configuration

Keep supply air and return air separated

Place the CRAC units facing perpendicular to the hot aisles

Install physical barriers for enhancing separation of hot and cold air

Place air supplies (perforated floor tiles or diffusers) in cold aisles only

Airflow Optimization – Overview

Closely match the supply air volume delivered to the cold aisle to the airflow required by the datacom equipment.

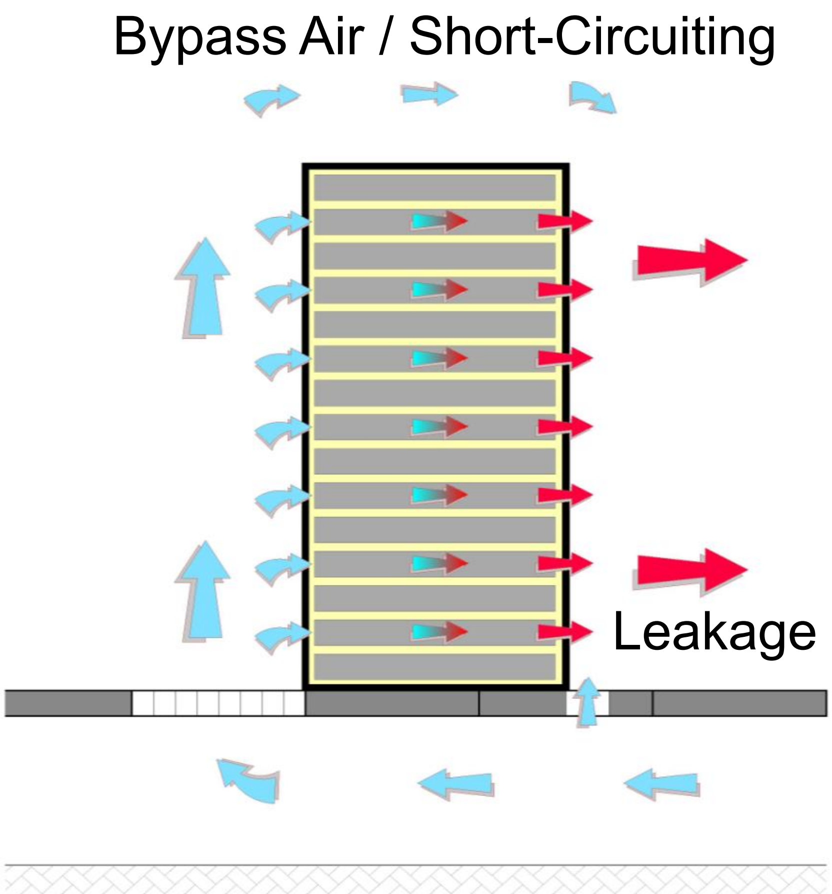
- Too little air will result in the recirculation of hot discharge air
- Too much air causes bypassing / short-circuiting resulting in excess fan energy and reduced return air temperatures

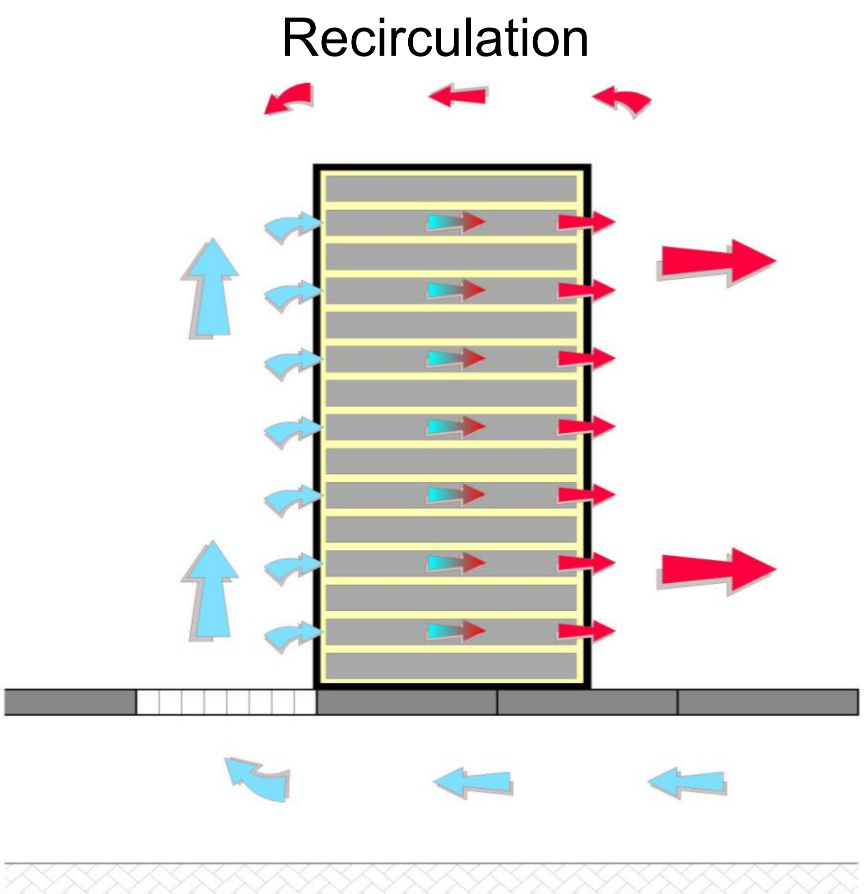
Maintain a consistent supply air temperature throughout the datacenter.

- Eliminate “hot spots” and “cold spots”
- Reduce recirculation and mal-distributed air

Raise supply air temperature as high as possible while conforming to datacom equipment inlet air requirements.

Airflow Optimization – Challenges

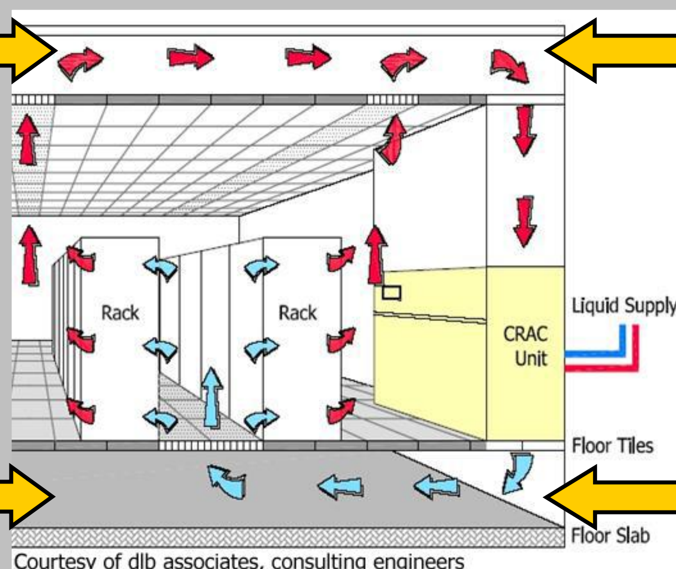




This scenario wastes cooling capacity

This scenario increases the inlet temperature to the equipment

Airflow Optimization – Congestion



Congested Floor & Ceiling Cavities

Consider The Impact That Congestion Has On The Airflow Patterns

Empty Floor & Ceiling Cavities

Airflow Optimization – Balancing

Theoretically, a raised floor plenum is at a constant static pressure; wherever a perforated tile is located, the airflow remain be constant.
In practice, there are significant pressure variations within the plenum:

- Cables and congestion in the floor plenum
- Increased velocity pressures near to supply air fans
- Raised floor not tall enough to allow static pressure to be realized

These pressure variations result in:

- Non-uniform airflow distribution
- Potential negative airflow if perforated tile is too close to supply fan

BALANCING is required to optimize airflow. Measure & REBALANCE whenever new datacom equipment or new cooling equipment is installed.

Airflow Optimization – Mal-Distributed Air

Mal-distributed air does not reach the intended location and is caused by:

- Leakage through air ducts / raised flooring (e.g. between floor tiles)
- Unsealed raised floor cutouts such as cable openings
- Incorrectly located air outlets / perforated floor tiles
  - Air outlets should ONLY be in cold aisles near active IT equipment

Varying Scenarios of % of Unintended Destination		
Scenario	**% of Air Distribution**	
	Intended Destination	**Unintended Destination**
1	**100 %**	**0 %**
2	**75 %**	**25 %**
3	**50 %**	**50 %**

Airflow Optimization – Takeaways

Optimized air distribution can improve energy efficiency ALTHOUGH the main objective is to ensure conformance to the thermal requirements

- Reduce air leakage & use grommets for cable cutouts
- Avoid cable congestion, especially under perforated floor tiles
- Avoid piping in areas that block airflow
- Balance (& rebalance) airflow per the datacom equipment requirements
- Select as high supply temperature as will provide sufficient cooling (maximizes chiller efficiency and the available economizer hours)
- Cooling coil capacity increases with warmer entering air temperatures
- Use Computational Fluid Dynamics (CFD) software to model airflow when practical

Liquid Cooling – Overview

Water and other liquids (dielectrics, glycols, and refrigerants) may be used for Datacom Equipment heat removal.

- Heat rejection with liquids typically uses LESS transport energy (**14.36** Air to Water Horsepower ratio).
- Liquid-to-liquid heat exchangers have closer approach temps than Liquid-to-air (coils), yielding increased economizer hours.

Heat Transfer		Resultant Energy Requirements			
Rate	ΔT	Heat Transfer Medium	Fluid Flow Rate	Conduit Size	Theoretical Horsepower
10 Tons	12°F	Forced Air	9217 cfm	34" Ø	3.63 Hp
		Water	20 gpm	2" Ø	.25 Hp

Liquid Cooling – Definitions

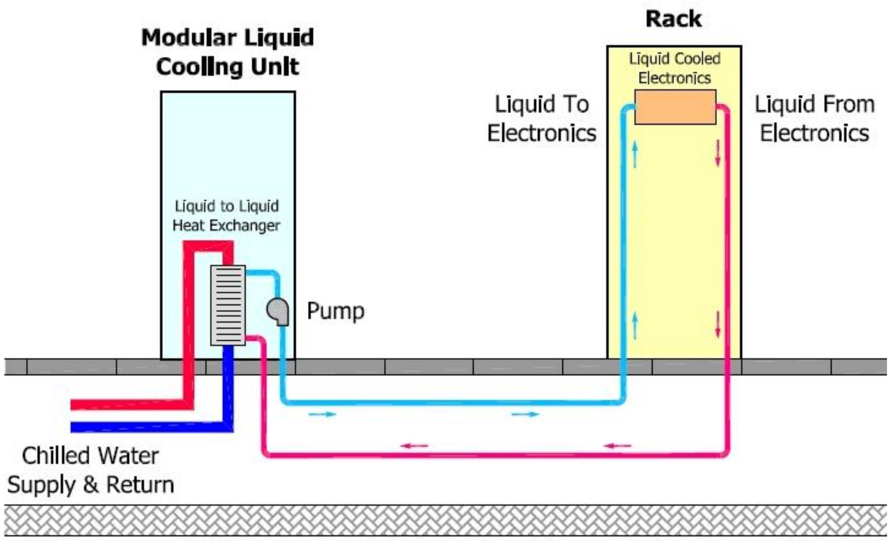
Liquid cooling: liquid must be supplied to an entity for operation

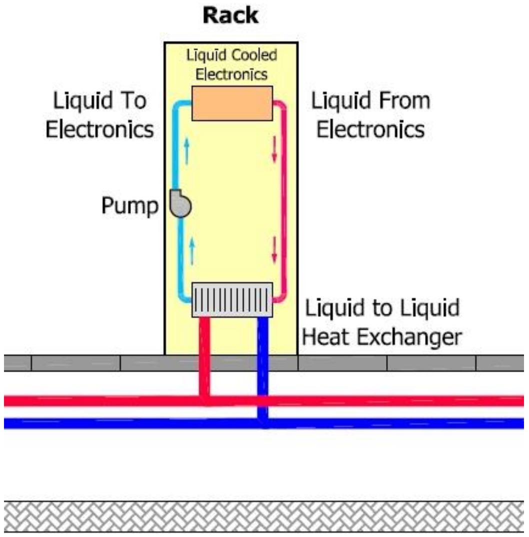
Air cooling: only air must be supplied to an entity for operation.

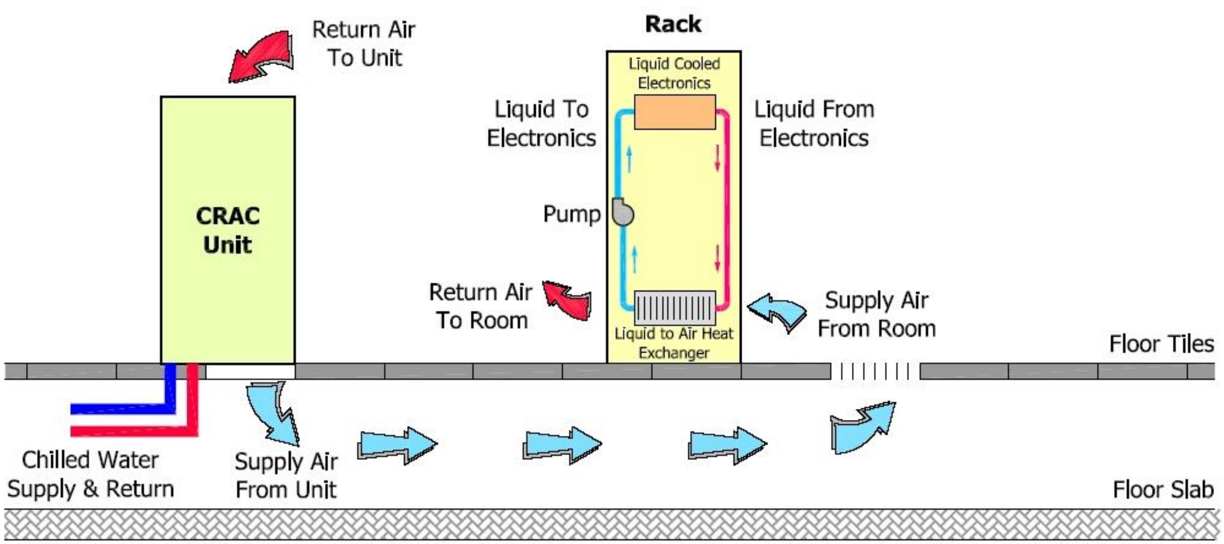
Liquid-cooled rack: liquid must be circulated to and from the rack or cabinet

Liquid-cooled datacom equipment: liquid must be circulated to and from the datacom equipment for operation

Liquid-cooled electronics: liquid is supplied directly to the electronics for cooling with no other form of heat transfer


Modular Liquid Cooling Unit
Liquid to Liquid Heat Exchanger
Pump
Rack
Liquid Cooled Electronics
Liquid To Electronics
Liquid From Electronics
Chilled Water Supply & Return


Rack
Liquid Cooled Electronics
Liquid To Electronics
Liquid From Electronics
Pump
Liquid to Liquid Heat Exchanger


Return Air To Unit
CRAC Unit
Rack
Liquid Cooled Electronics
Liquid To Electronics
Liquid From Electronics
Pump
Return Air To Room
Liquid to Air Heat Exchanger
Supply Air From Room
Floor Tiles
Chilled Water Supply & Return
Supply Air From Unit
Floor Slab

Liquid Cooling – Systems / Loops

Datacom Equipment Cooling System (DECS)

- Performs heat transfer from heat-producing IT components to a fluid-cooled heat exchanger contained in the rack. Does not extend beyond the rack.

Technology Cooling System (TCS)

- Dedicated heat transfer loop between the IT equipment cooling system and the chilled-water system. Typically does not extend beyond the server room.

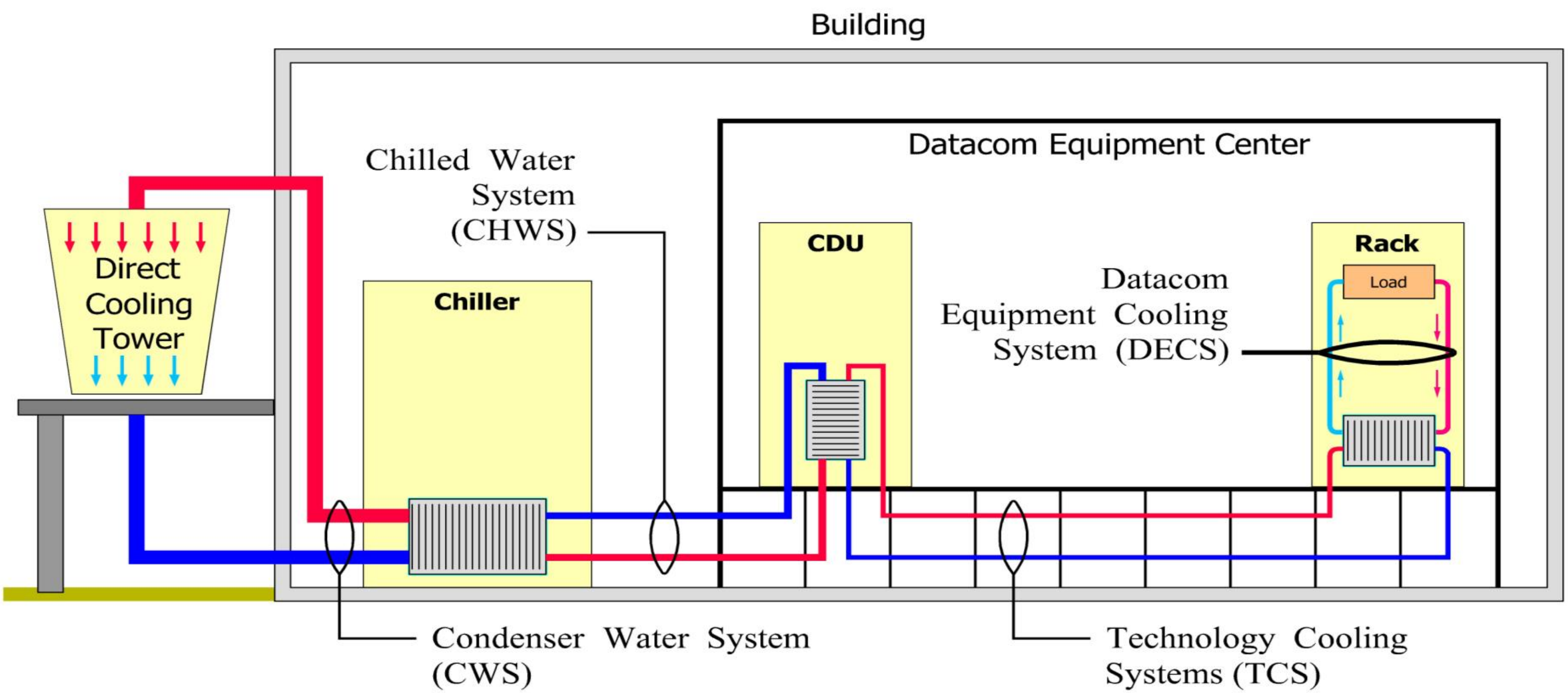
Chilled-Water System (CHWS)

- Typically connects centrally located chillers to multiple CDUs or CRAHs. Extends between the server room and the cooling plant.

Condenser-Water System (CWS)

- Connects the heat rejection equipment to the chillers or CRAC unit economizer coils. Typically extends between outdoor equipment and indoor equipment.

Liquid Cooling – Systems / Loops



<u>Liquid Cooling Systems/Loops within a Data Center</u>

Liquid Cooling – Takeaways

Why use Liquid Cooling?

- Achieve lower processor temperatures (increased performance and / or reliability).
- Elevate cooling media temperatures within IT equipment increasing “free cooling” opportunities.
- To directly contact electrically carrying components (NOT water!).

Why NOT use Liquid Cooling?

- Interruption of liquid flow may cause near INSTANTANEOUS over-heating of electronics.
- Introduction of liquids within close proximity to electronics.
- The need for air-cooling for legacy datacom equipment may still exist.

Show & Tell

Video – 3

Controls and Energy Management – Overview

Controls systems can ensure both reliability and energy efficiency.

A higher supply air temperature typically results in

- Increased economizer hours & more efficient mechanical cooling
- Less “safety factor” in regards to IT inlet conditions

Widen temperature and humidity control ranges

- Increase the operational “deadbands” & decrease the potential for systems to “fight” each other
- Reduced usage of humidification and dehumidification

Part-load operation is an opportunity for significant energy savings.

- Need effective variable speed and variable capacity control

Controls and Energy Management – Takeaways

Control schemes:

- Vary fan speed to maintain differential pressure set-point under floor
- Reset differential pressure set-point by highest rack temperature
- Use dew-point humidity control, NOT relative humidity (%RH)
- Optimize the quantity of cooling equipment running under part-load

Sense and monitor:

- Optimal sensor quality, location, quantity (multiple averaging), & calibration
- Monitor IT equipment inlet conditions for environmental compliance
- Measure & trend energy consumption

Cooling Services / Systems – Recap

There is a SIGNIFICANT opportunity for energy savings in the design / operation of datacenter cooling systems:

- Economizer Cycles / Free Cooling
- Variable Speed Fans / Pumps / Compressors
- Airflow Optimization
- Increasing the server area temperature

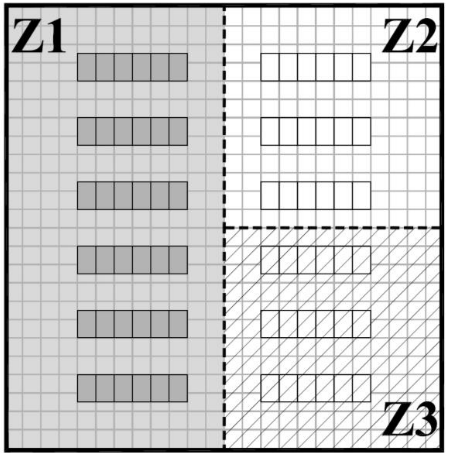
Techniques are applicable to both NEW and EXISTING facilities but must be evaluated in a holistic manner (determine the TCO).

Plan cooling services / systems to meet the needs of today while considering the needs of the future.

Source: LBNL

Cooling – Planning using Zones

Dividing one server area into many zones facilitates the planning and / or implementation of various cooling strategies.



Topic	Zone 1	Zone 2	Zone 3
Localized Cooling	None	Rear-door	In-Row
Cooling Source	Air	Air & Liquid	Liquid
IT Airflow Configuration	F-R	F-R	S-S
Air Distribution	VUF	VUF	VOH
Cold Aisle Containment	No	No	Yes

Cooling – Equipment Load Efficiencies

Equipment Selection Alternatives					
Description	Efficiency				
	10% Load	25% Load	50% Load	75% Load	100% Load

Complete this table for each major piece of equipment.

Cooling – Equipment Load Efficiencies

Equipment Selection Alternatives					
Description	Efficiency				
	10% Load	25% Load	50% Load	75% Load	100% Load
Chiller (Air-cooled)	70	75	80	85	90
Chiller (Water-cooled)	70	85	90	95	95

Complete this table for each major piece of equipment.

Cooling Services Future Allocation	
Topic	**Allocation Above Day 1 Capacity in %**
Cooling Plant	
Space	
Equipment	
Power Supply Space & Roughing	
Power Supply Equipment	
Cooling Distribution	
Space	
Distribution	
Cooling Terminal	
Space	
Distribution	
Power Supply Space & Roughing	
Power Supply Equipment	

Cooling Services Future Allocation	
Topic	Allocation Above Day 1 Capacity in %
Cooling Plant	-
Space	30
Equipment	50
Power Supply Space & Roughing	50
Power Supply Equipment	70
Cooling Distribution	-
Space	20
Distribution	100
Cooling Terminal	-
Space	20
Distribution	30
Power Supply Space & Roughing	50
Power Supply Equipment	100

ASHRAE – Save Energy Now Presentation Series

Electrical Services / Systems

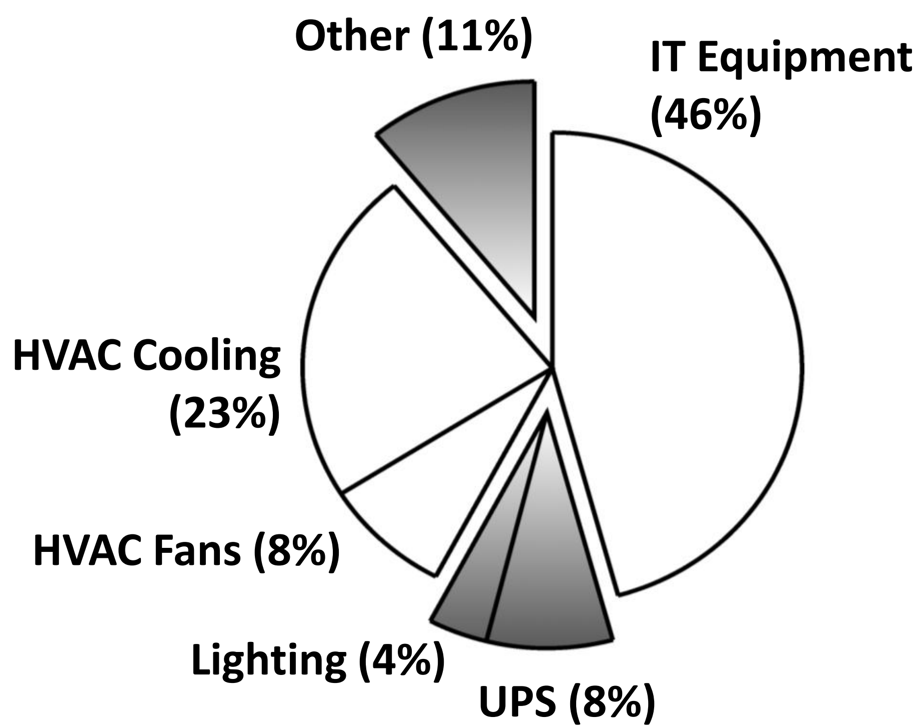
Opening Comments

Distribution Losses For Data Centers:

- An average 8% loss for Uninterruptible Power Supply (UPS) equipment.
- Electrical distribution losses such as transformers also make up some component of the 11% of 'Other Losses.'

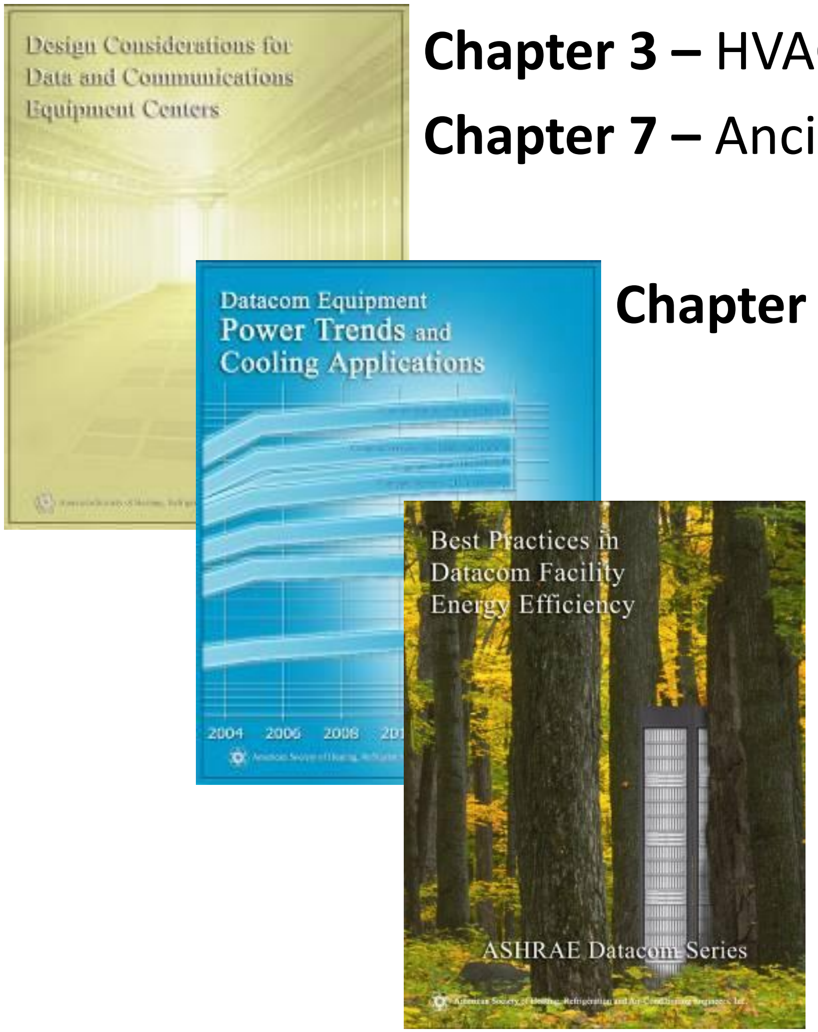
Agenda

- Electrical Distribution Systems
  - Components
  - Energy Efficiencies
- Other Systems
  - Lighting
  - Standby generation
- Emerging Technologies



Typical Data Center Power Allocation

Pertinent Chapters From ASHRAE Datacom Series



Chapter 3 – HVAC Load Considerations

Chapter 7 – Ancillary Spaces

Chapter 3 – Load Trends And Their Application

Chapter 8 – Electrical Distribution Equipment

Chapter 11 – Emerging Technologies and Future Research

Electrical Systems - Components

Utility Transformer → ELECTRICAL DISTRIBUTION → **Uninterruptible Power Supply (UPS)** → **Power Distribution Unit (PDU)** → **IT Load**

Generator Backup → ELECTRICAL DISTRIBUTION → **Other Loads (Cooling, Lighting, Etc)**

Utility Transformer
- High voltage power lines
- Transformer

Uninterruptible Power Supply (UPS)
- Rectifiers / Inverters
- Batteries

Power Distribution Unit (PDU)
- Panels
- Transformers
- Cabling

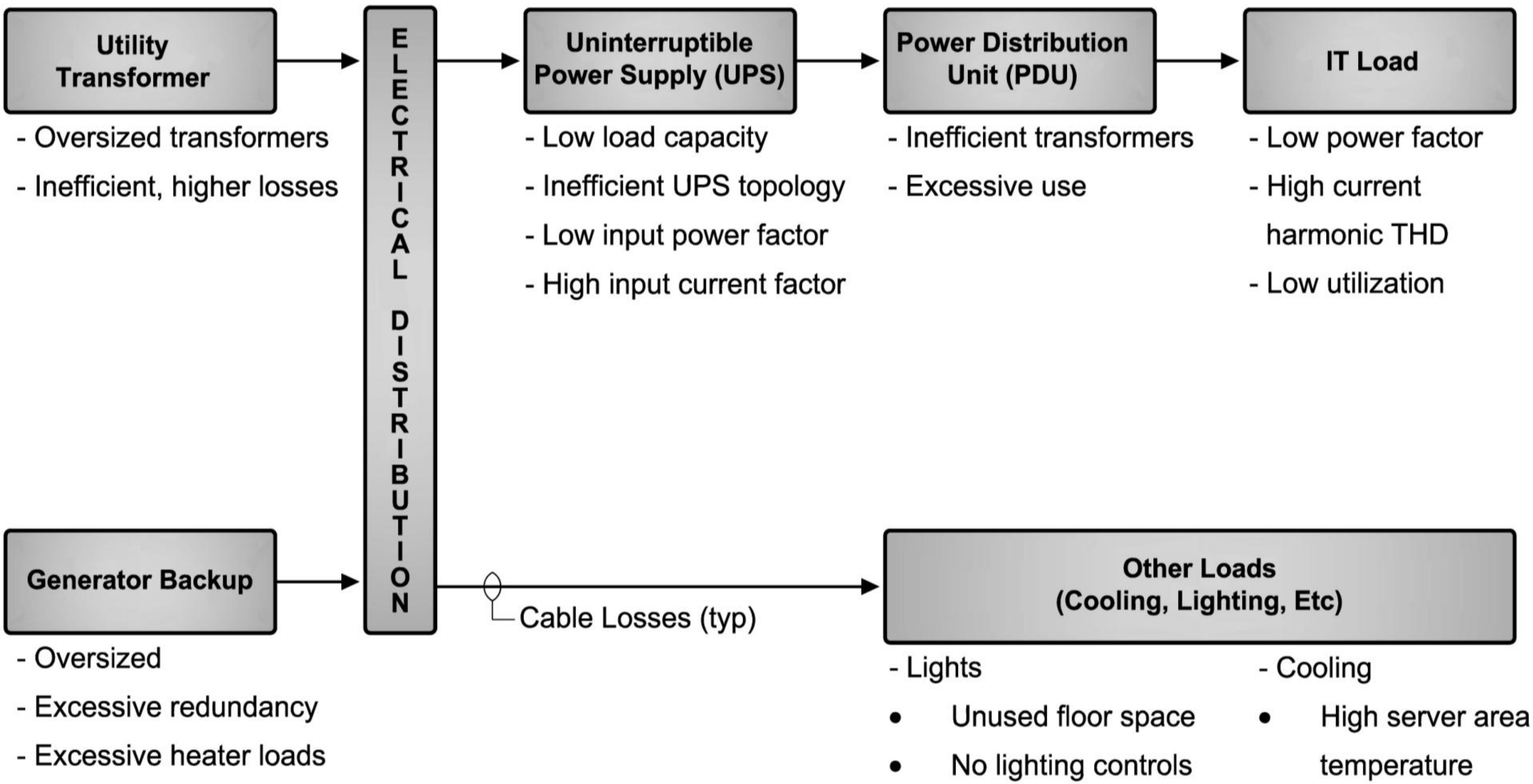
IT Load
- Power supply units
- Servers
- Computers

Generator Backup
- Engine
- Controls system

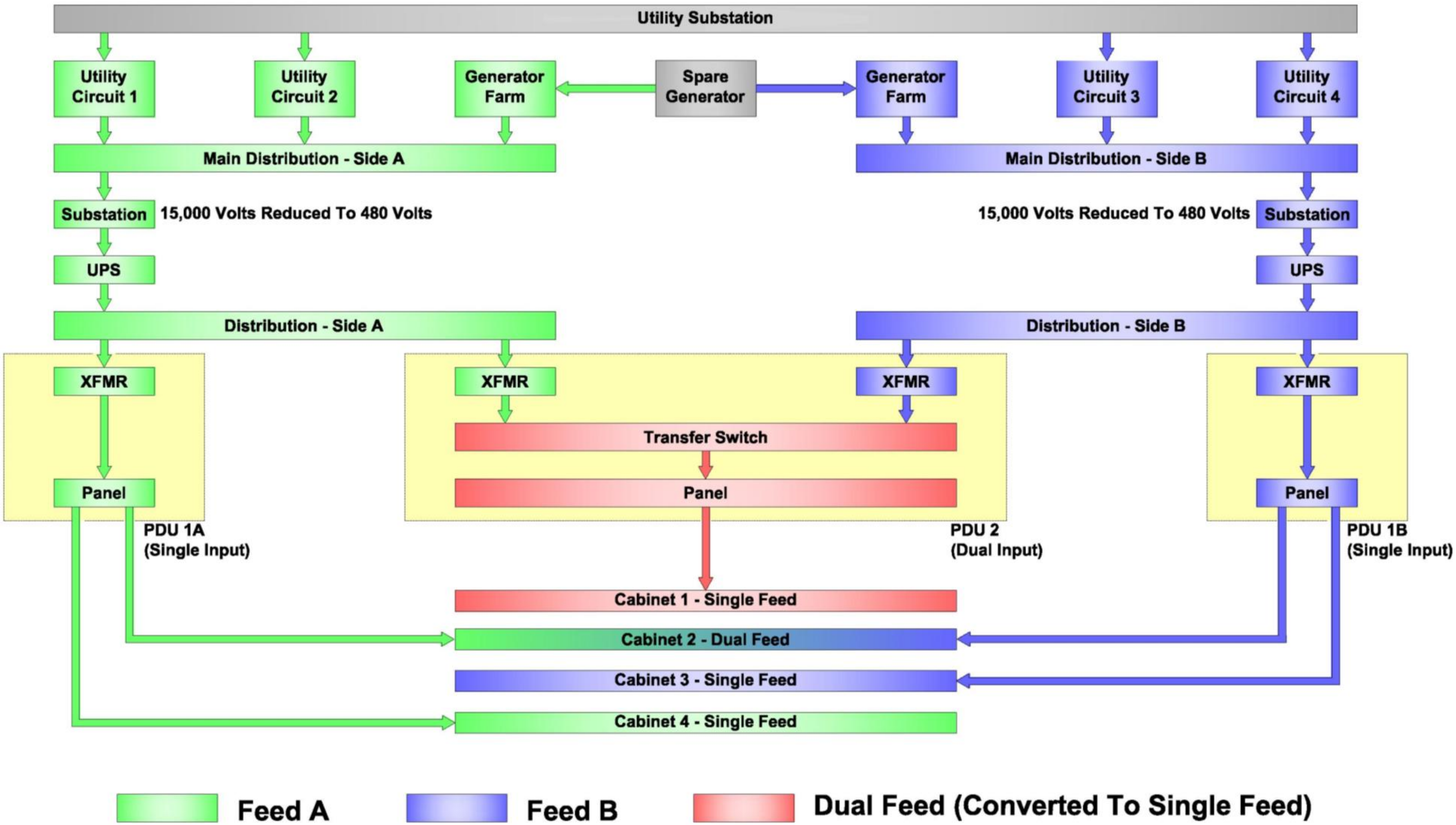
ELECTRICAL DISTRIBUTION
- Switchboards
- Substations & transformers
- Panels

Other Loads (Cooling, Lighting, Etc)
- Lights
- Cooling

Electrical Systems – Energy Inefficiency



Electrical Systems - Block Diagram



Electrical Systems - Efficiency Best Practices

The Electrical distribution requires carefully planning to reduce impedances, hence, heat load.

- Choose UPSs that operate with high efficiency throughout their expected operating range. UPS efficiency varies with the type of UPS.
  - Line-interactive flywheel UPS efficiency is 98%
  - Double conversion UPS efficiency is 86-95% at full load
- Redundancy should be used only up to the required level; there may be an efficiency penalty for additional redundancy
- Select high efficiency transformers
- Limit conductor runs by installing Power Distribution Units (PDUs) as close to the rack load as possible.
  - Distribute high voltage AC or DC power to the point of use.
  - Electrical distribution at an increased voltage reduces the heat loss from the cables and is more energy efficient

Electrical Systems - Efficiency Issues

Power conversions – numerous and wasteful

- Each conversion loses some power and creates heat
  - A typical distribution voltage within a building is 480 / 277 Vac and is often stepped-down via a transformer to 208 / 120 Vac
- Not optimized in terms of voltages or efficiency
  - Typical datacom equipment is rated at is 100-127 /200-240 Vac
- Oversized equipment – capacity unused for most of its life
- Reliability requirement (2N or N+1) often force this

Older equipment – inefficient

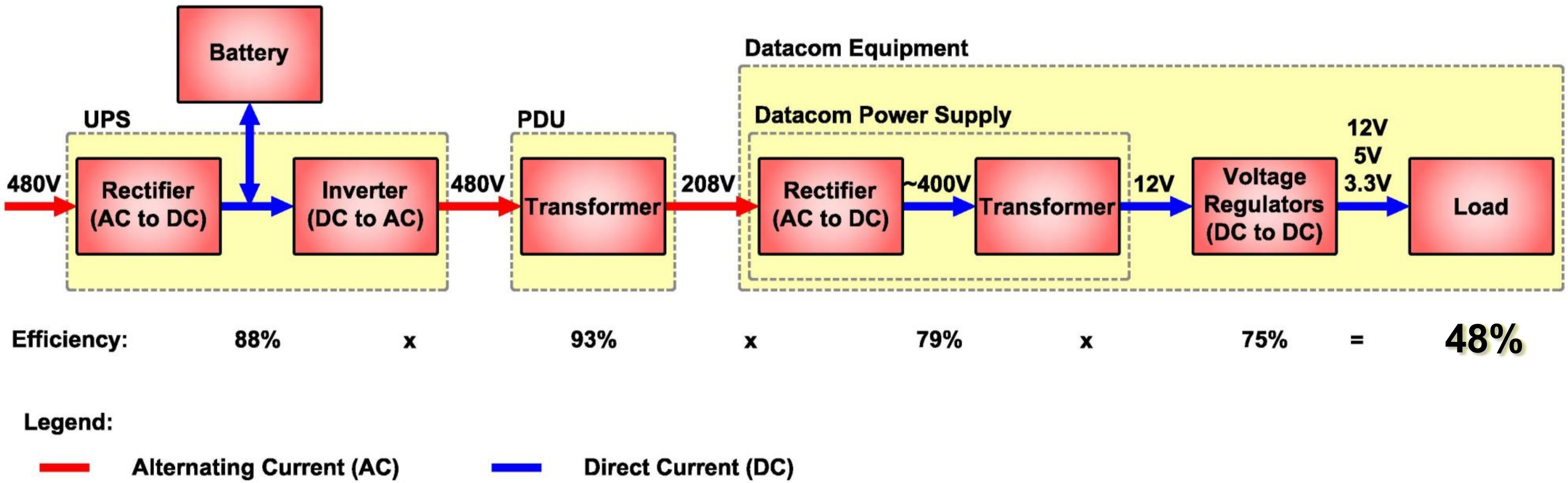
Unused equipment – on and not doing anything

Lighting – inefficient and not controlled

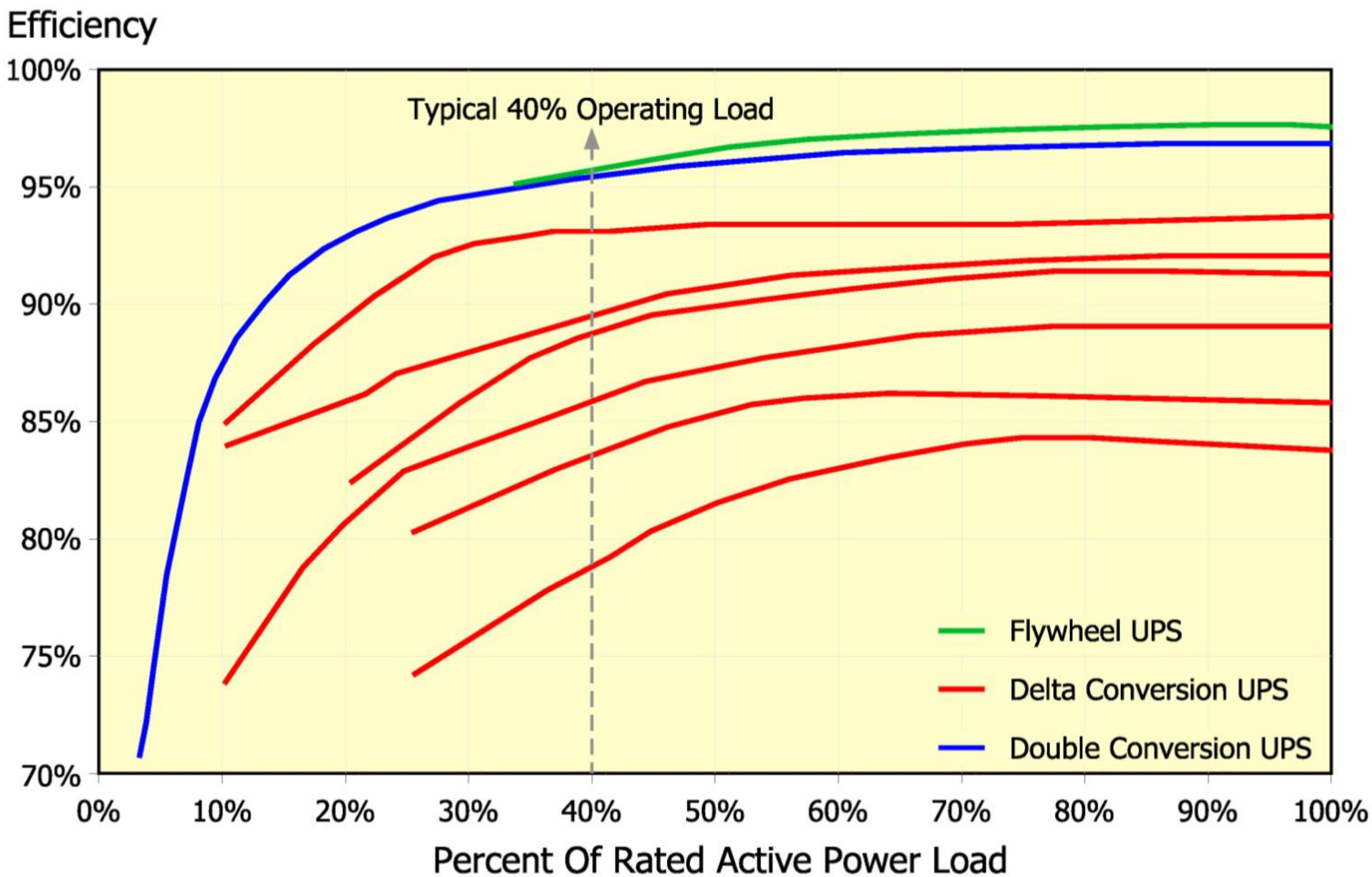
Electrical Systems - Losses

Efficiencies are compounded as power flows downstream:

- Several relatively efficient components in series can dramatically lower the overall efficiency.
- The example below shows less than half the power delivered actually reaches the load.



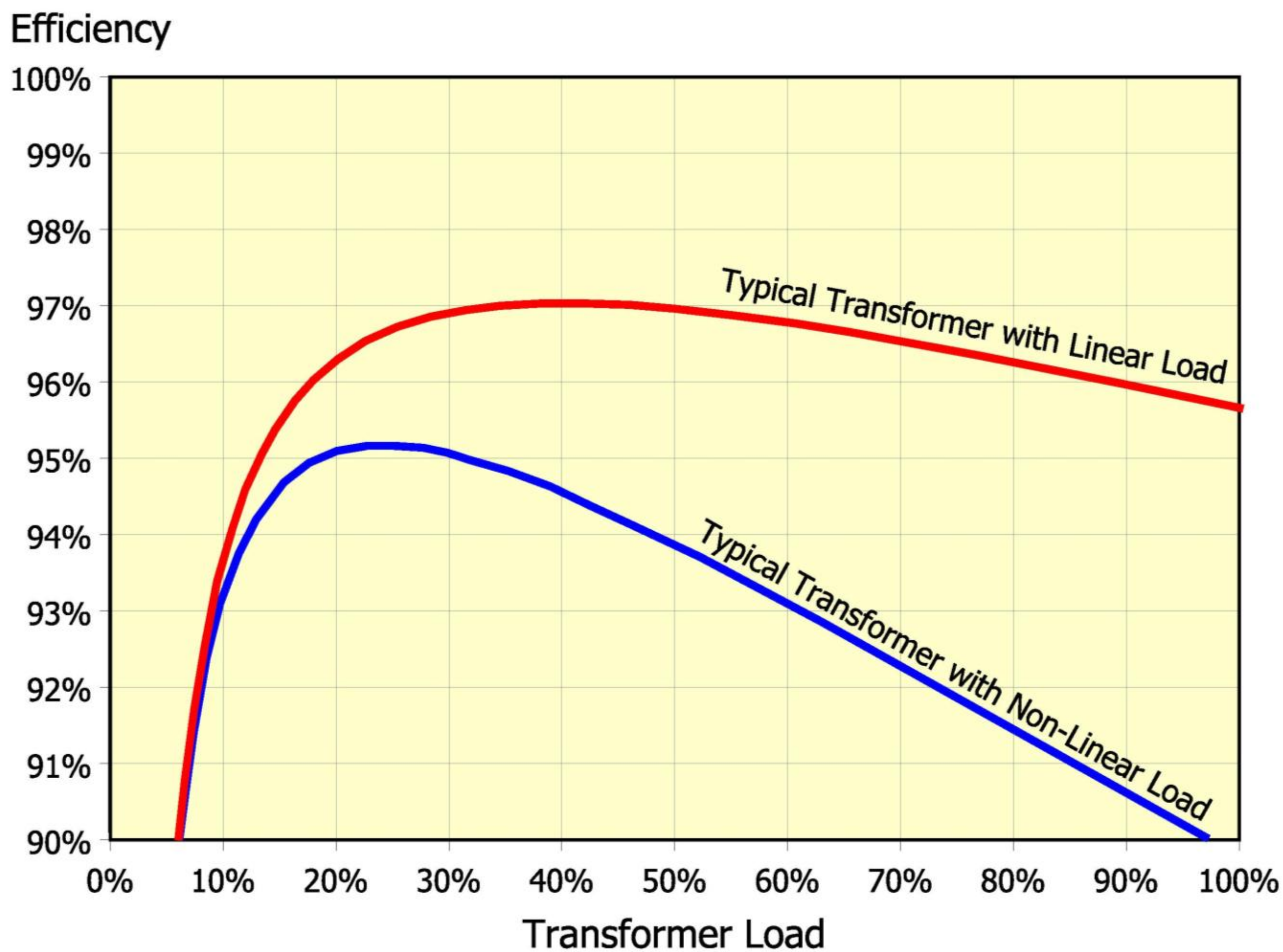
Electrical Systems – UPS Efficiency Overview



Source: LBNL / EPRI

Based on linear loading

Electrical Systems - Transformer Efficiency Overview



Source: PowerSmiths

Significant variation in efficiency over load range

Electrical Systems - Power Distribution

A conventional datacom facility utilizes AC (alternating current) power distribution, but components within datacom equipment typically require DC (direct current) power.

- There could be 6 or more stages of power conversion before the utility power is delivered to the datacom electronics.
  - Each conversion is a potential source of power loss and wasted energy
  - Distributing DC power can eliminate several stages of power conversion saving energy to the IT equipment and cooling.
    - » Use DC for lighting & variable speed drives to further improve efficiency

Several DC voltages in use or being explored include:

- -48V used in telecom and rack distribution
- 425V used in proprietary system along with 48V rack distribution
- 380V (actually 350-400V) used in Japan and Europe. Demonstrated in US by LBNL

Electrical Systems – Other Systems

Lighting

- Datacom spaces are often unoccupied
  - Switch off lights in unused / unoccupied areas or rooms (UPS, Battery, Switchgear, etc)
  - Lighting controls such as occupancy sensors are well proven

Standby Generators

- Opportunity may be to reduce or eliminate heating, batteries, & chargers
- Heaters (many operating hours) used to maintain component / fluid temperatures use more electricity than the generator will typically produce over its lifetime (few operating hours)
  - Check with the generator manufacturer on how to reduce the overall energy consumption of block heaters (Hot Water Jacket(s) - HWJ), e.g. temperature control

Key Takeaways

- Choose highly efficient components
- Every power conversion (AC-DC, DC-AC, AC-AC, DC-DC) decreases overall efficiency and creates heat
- Efficiency decreases when systems are lightly loaded
- Distributing higher voltage reduces the number of power conversions and reduces capital cost (conductor size is smaller)
  - Direct Current (DC) systems can reduce conversion losses
- Efficiency is inversely proportional to redundancy
  - Consider the minimum redundancy required

Video – 4

Electric Utility Assessment

Topic	Below Average	Average	Above Average
Age / condition			
Generation			
Transmission			
Substations			
Substation to Site			
Spare Capacity			
Generation			
Transmission			
Substations			
Substation to Site			
History of Outages			

Electric Utility Assessment

Topic	Below Average	Average	Above Average
Age / condition			
Generation	x		
Transmission		x	
Substations			x
Substation to Site	x		
Spare Capacity			
Generation	x		
Transmission		x	
Substations			x
Substation to Site			x
History of Outages		x	

On Site Generation (normal or emergency power)

Topic	Below Average	Average	Above Average
Fuel Source			
Capacity Available / Day			
Number of Available Suppliers			
Impact of Supply during a Storm Event			
Cost of Fuel			
Emissions Restrictions			
Availability of Qualified Mechanics			
Local Availability of MOST Parts			

On Site Generation (normal or emergency power)

Topic	Below Average	Average	Above Average
Fuel Source			
Capacity Available / Day			x
Number of Available Suppliers			x
Impact of Supply during a Storm Event	x		
Cost of Fuel		x	
Emissions Restrictions	x		
Availability of Qualified Mechanics		x	
Local Availability of MOST Parts	x		

Emerging Technologies - Distributed Generation and CCHP

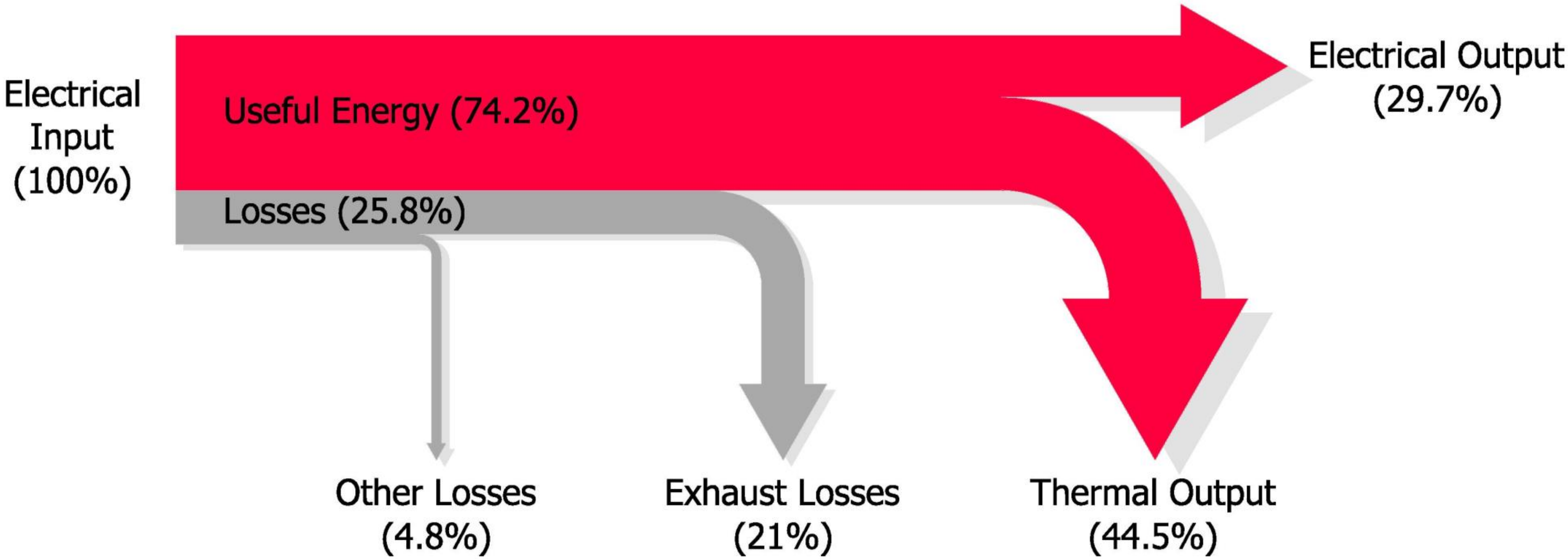
A traditional data center typically uses the power from the utility company as the primary source of power under normal conditions.

In the event of a utility outage, a backup power source (typically an on-site generator) provides power on a temporary basis until the utility power is restored and is considered stable.

Distributed Generation (DG) is a term that describes having a locally generated primary power source operating on a continuous basis (solar, photovoltaic, wind turbines, engine generators, turbine generators and fuel cells).

Some of these technologies have a suitable waste product (heat) that can be used as the input energy for the cooling as a part of a CCHP system.

Emerging Technologies - Opportunities for Heat Recovery



Offsetting building thermal output by recycling the waste heat energy available at site can:

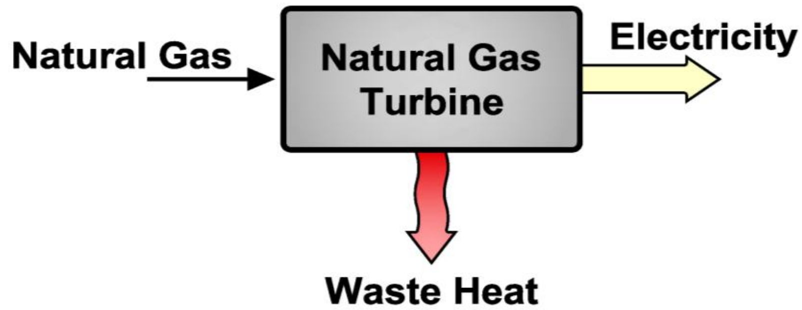
- Reduce costs and increase reliability
- Increase efficiency and reduces fossil fuel combustion

Emerging Technologies - CCHP Technology

In a conventional system, natural gas is used to create electricity using a gas turbine.

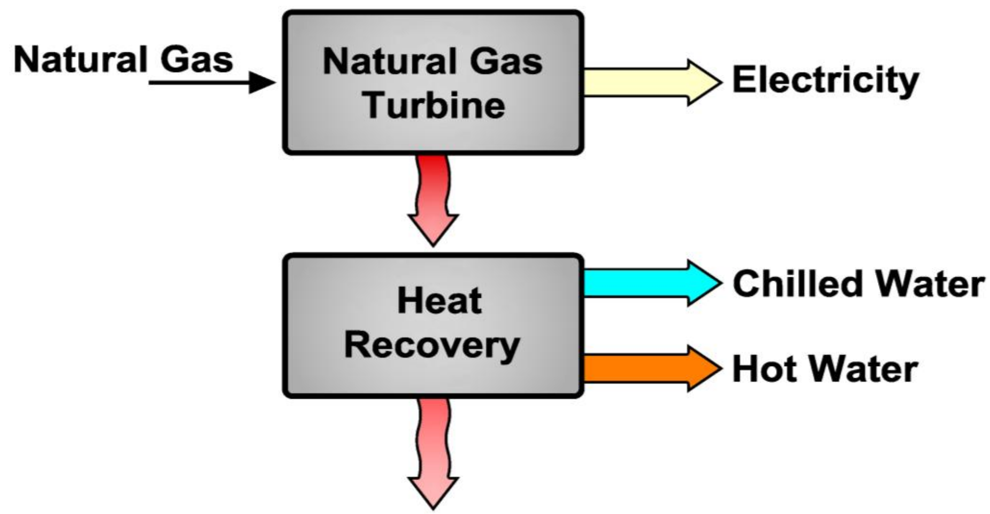
- Waste heat is discarded.

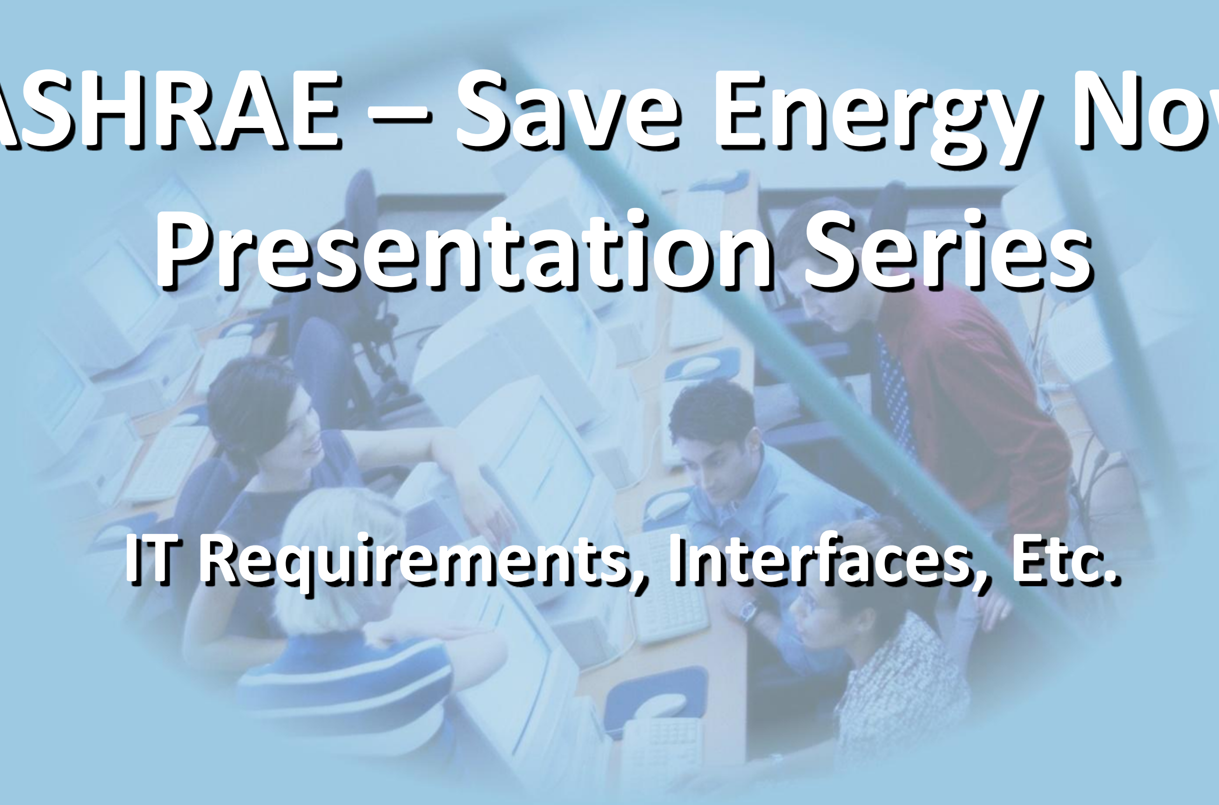
Conventional System



In a CCHP system, waste heat is recovered and used (usually by an absorption process, e.g. absorption chiller) to produce chilled or hot water for use in the data center.

CCHP System





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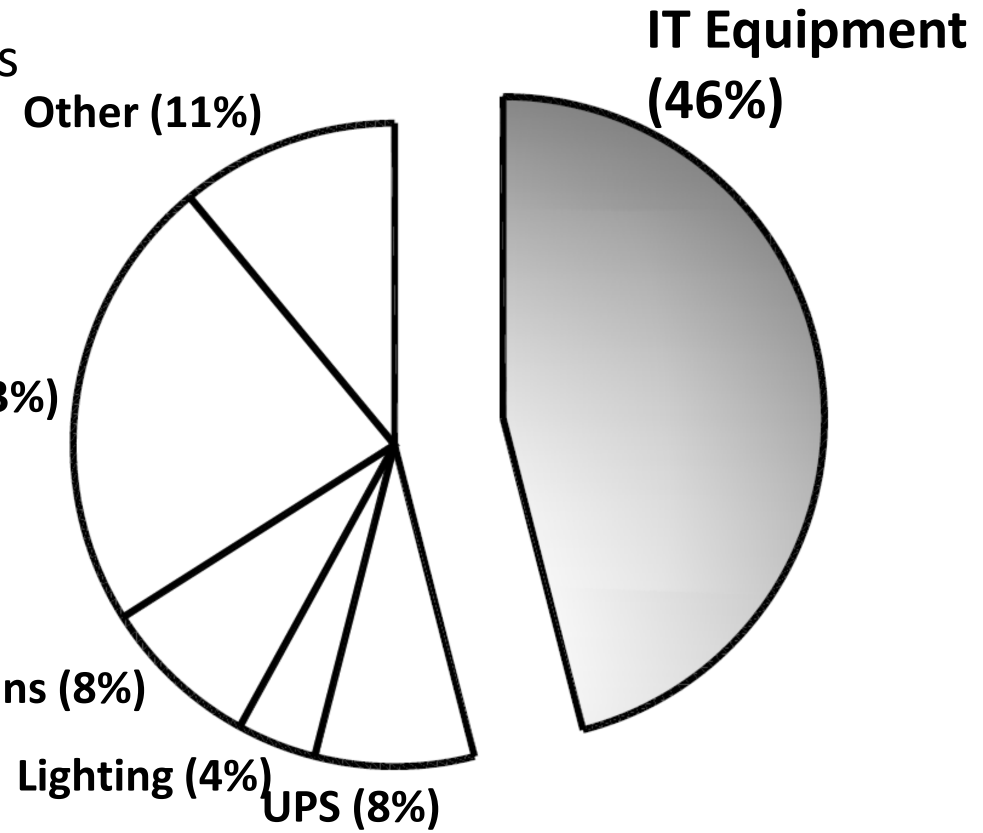
IT Requirements, Interfaces, Etc.

Opening Comments

The single largest component of energy usage in data centers is that used by the IT equipment itself.

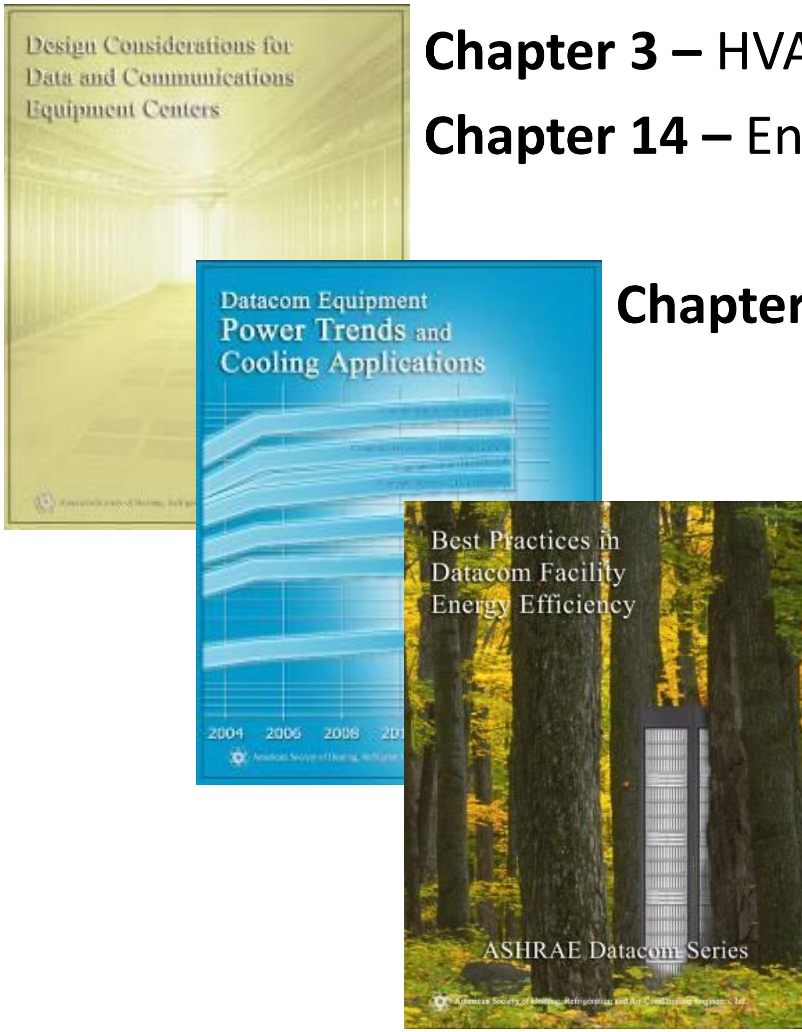
- IT Environmental Specifications
- IT Provisioning
- Monitoring
- IT Equipment
- Tools
- Decommissioning



Typical Data Center Power Allocation

Source: LBNL

Pertinent Chapters From ASHRAE Datacom Series



Chapter 3 – HVAC Load Considerations

Chapter 14 – Energy Efficiency

Chapter 3 – Load Trends And Their Application

Chapter 8 – Electrical Distribution Equipment

IT Equipment Environment – Updated Thermal Guidelines

ASHRAE's Thermal Guidelines Book was published in 2004 and the environmental conditions envelope section was updated in 2008.

The change in 2008:

- Expands the recommended temperature range
- Implements Dew Point range rather than humidity range
- Provides greater flexibility in facility operations
- Potentially reduces energy consumption in Data Centers – reduced cooling and additional economizer hours (although server fan energy may increase due to higher inlet temperatures)
- Recommendations maintain high reliability
- Is supported by all the major IT equipment manufacturers

Recommended vs. Allowable Specification Envelopes

Recommended – The purpose of the recommended envelope is to give guidance to data center operators on maintaining high reliability and also operating their data centers in the most energy efficient manner.

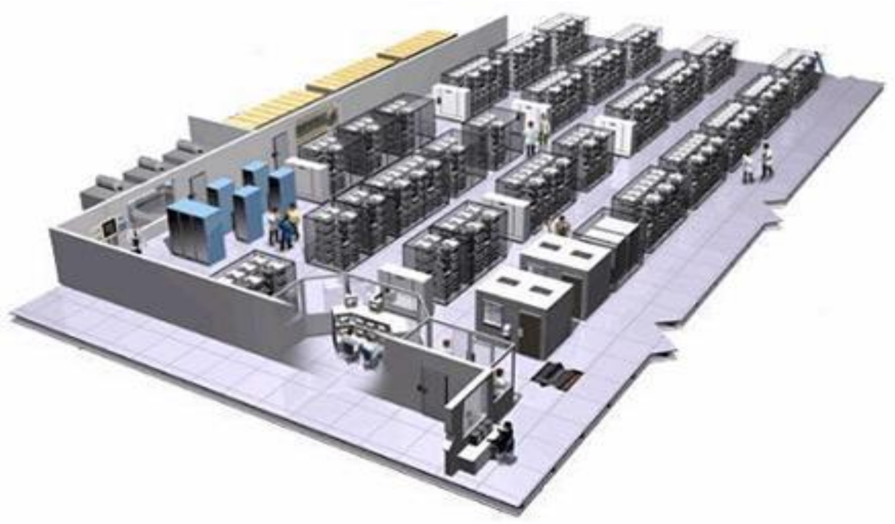
Allowable – The allowable envelope is where the IT manufacturers test their equipment in order to verify that the equipment will function within those environmental boundaries.

Prolonged Exposure – Prolonged exposure of operating equipment to conditions outside its recommended range, especially approaching the extremes of the allowable operating environment, can result in decreased equipment reliability and longevity. Occasional, short term excursions into the allowable envelope MAY be acceptable.

IT Equipment Environment – Class Definition

What are the environmental operating conditions?

Recommended & Allowable Environmental Conditions vary depending on the application, scale & type of electronic equipment that is being cooled.



Class 2 – Office Space

Class 1 – Data Center

Class 3 – Home Office

Class 4 – Point of Sale

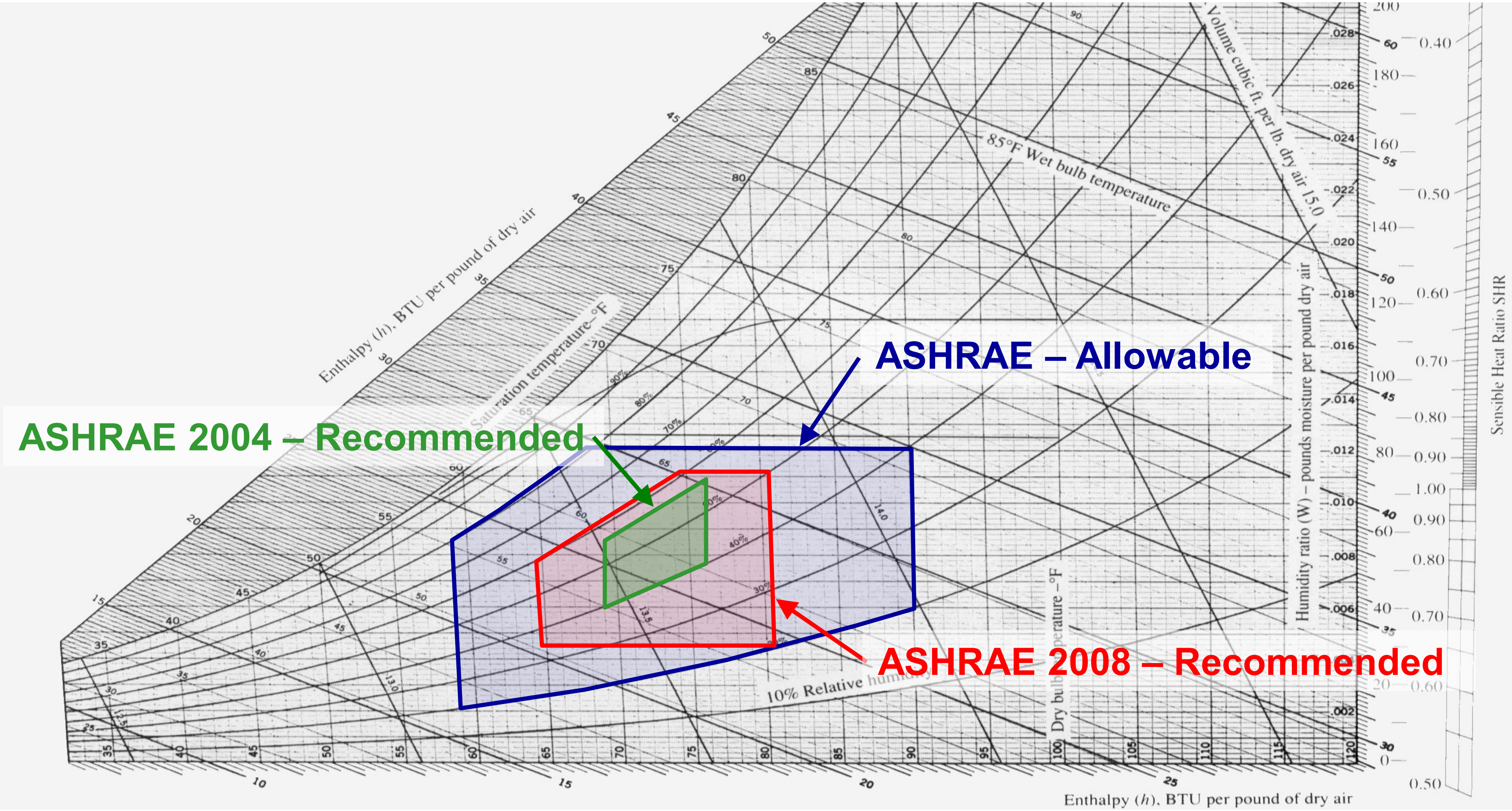
IT Equipment Environment Specifications

Product Powered **'ON'** (Operational) Specifications

Class	Dry Bulb Temperature °F		% Relative Humidity		Max. Dew Point °F	Max Rate of Change °F / hr
	Allowable	Recommended	Allowable	Recommended		
1	**59 to 89.6**	**64.4 to 80.6**	**20 to 80**	**41.9°F DP to 60% RH and 59°F**	**62.6**	**9**
2	**50 to 95**	**64.4 to 80.6**	**20 to 80**	**41.9°F DP to 60% RH and 59°F**	**69.8**	**9**
3	**41 to 95**	**N/A**	**8 to 80**	**N/A**	**82.4**	**N/A**
4	**41 to 104**	**N/A**	**8 to 80**	**N/A**	**82.4**	**N/A**

Note: Environment Specifications based on a max. elevation of 10,000 ft

IT Equipment Environment Specifications



IT Equipment Environment – Heat & Airflow

Nameplate Data versus ASHRAE Equipment Thermal Report

Datacom equipment manufacturers' nameplate data has a regulatory safety focus & the values are not an accurate reflection of heat rejection.

ASHRAE's Thermal Guidelines for Data Processing Environments requires the datacom equipment manufacturer to publish the following for each product:

- Steady state heat release numbers in watts
- Maximum & nominal airflow quantity & pattern under normal operating conditions
- Variations of above based on specific equipment configurations via predictive algorithms.

This information is to be listed in the form of an Equipment Thermal Report.

Similar reporting of these metrics will be required under the new EPA Energy Star Program.

Typical Thermal Report Example: Generic Server

Configuration		Condition				
		Typical Heat Release	Airflow			
			Nominal		Max. (@ 35°C)	
Description	Model	Watts @ 110V	cfm	(m^3/h)	cfm	(m^3/h)
Minimum	1-way 1.5 GHz Processor 16GB memory	420	26	44	40	68
Full	2-way 1.65 GHz Processor Max. memory	600	30	51	45	76
Typical	1-way 1.65 GHz Processor 16GB memory	450	26	44	40	68

Note: System Dimensions and Weight are common for all configurations shown

Thermal Report vs. Nameplate Comparison

Nameplate – 920 W (1 kVA w/ PF = 0.92)

ASHRAE thermal report – 420 to **600** W

IT Provisioning

Data center IT equipment can be broken down between broad categories for Servers (Compute), Storage, and Network equipment.

Agreements (formal or informal) between the data center owner and their customers constitute Service Level Agreements (SLAs).

SLAs can define and enforce power and cooling issues such as boundary conditions between IT equipment and the facility infrastructure / environment supporting it.

SLAs are "*a formalized set of service / performance objectives*" (preferably the specific metrics are described in a single page).

SLAs are commonly used in colocation types of data centers but SLAs can also be established between two departments in the same organization.

IT Provisioning

The equipment and software are provisioned on a regular cadence dictated by the business processes and IT developments/improvements.

- Regular provisioning requires SLA reviews and usage monitoring
- IT provisioning should entail an Energy Activity Policy
  - Maintenance schedules
  - Full load and cooling
  - Opportunities to dynamically reduce IT load based on resume latencies and triggers

IT Provisioning

Transition obligations from SLAs to the necessary IT infrastructure:

SLA

Obligations:

- Future Revisions
- Reliability
- Response Time
- Availability
- Storage Tier
- Retention
- Security

IT Infrastructure

Required to Meet Obligations:

- Server Capacity
- Redundancy
- Storage Availability
- Up-Time
- Network Speed

What Provisioning Information Do You Have?

- What's Service Level Agreements (SLA) do you have?
- Availability requirements?
- Peak Loads?
- Warning Levels?
- Inventory Levels – Compute, Network, Storage?
- Capacity and operational latencies.
- Maintenance, inventory, and verification cycles?
- Retirement, consolidation, expansion?

DEVELOP AN IT PROVISIONING STRATEGY!

Monitoring

Monitoring facilitates the quantification of effectiveness and efficiency of data centers.

Two metrics can be used to determine the energy efficiency of a data center:

Data Center Efficiency (DCE)

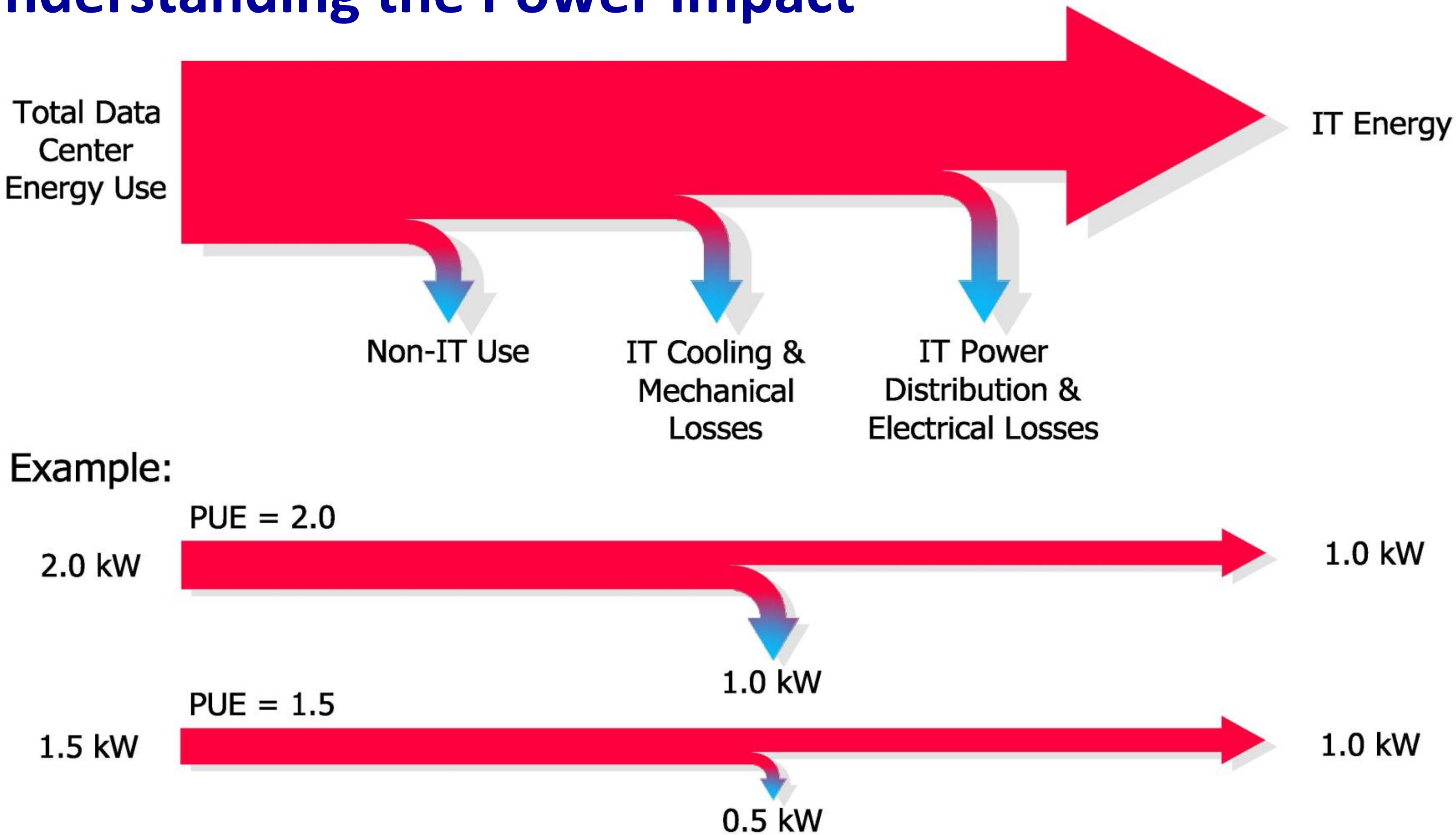
$$\mathrm{DCE} = \frac{\text{IT Equipment Power}}{\text{Total Facility Power}} \quad \text{(Green Grid, 2007)}$$

Power Usage Effectiveness (PUE)

$$\mathrm{PUE} = \frac{\text{Total Facility Power}}{\text{IT Equipment Power}} \quad \text{(Green Grid, 2007)}$$

Plan data collection to better manage energy consumption

Understanding the Power Impact

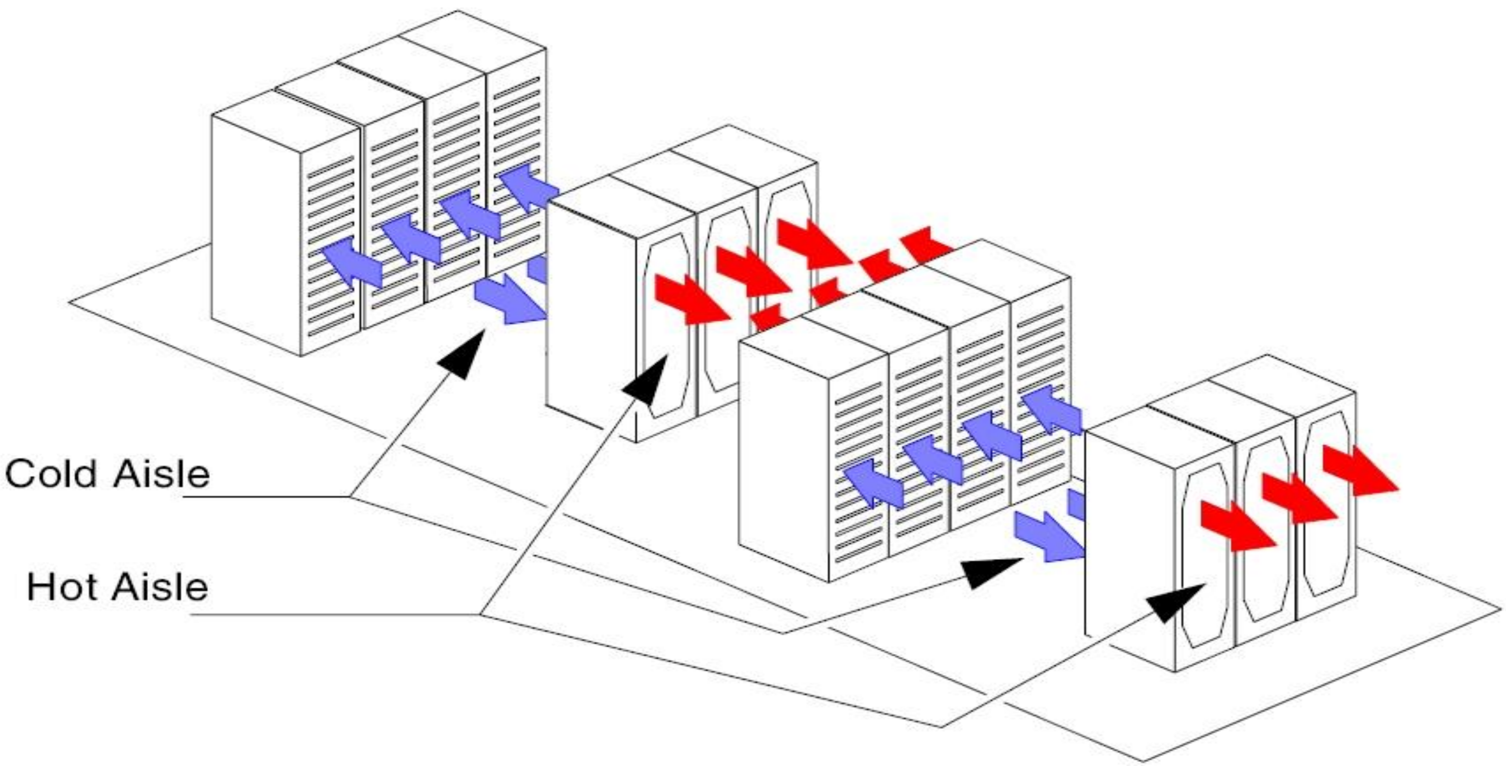


<u>25% Energy Savings</u> going from PUE = 2.0 to 1.5

Measurement at Inlet of IT Equipment

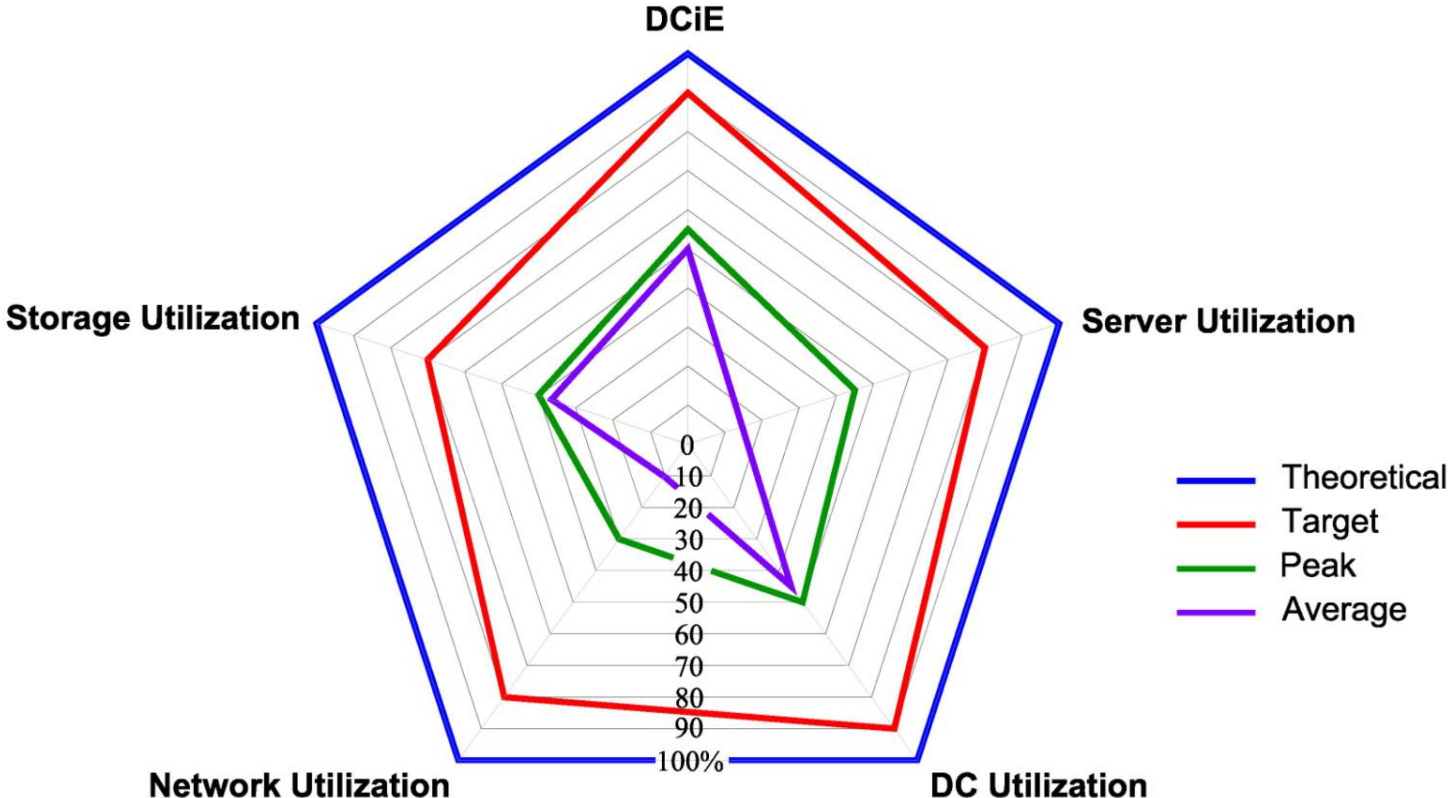
AIR INLET to datacom equipment **IS** the important specification to meet.

OUTLET temperature is **NOT** important to datacom equipment.



Overall Data Center Productivity Metrics

- Plot utilization on a radial graph
- A visual assessment of how resources are being used



Source: The Green Grid

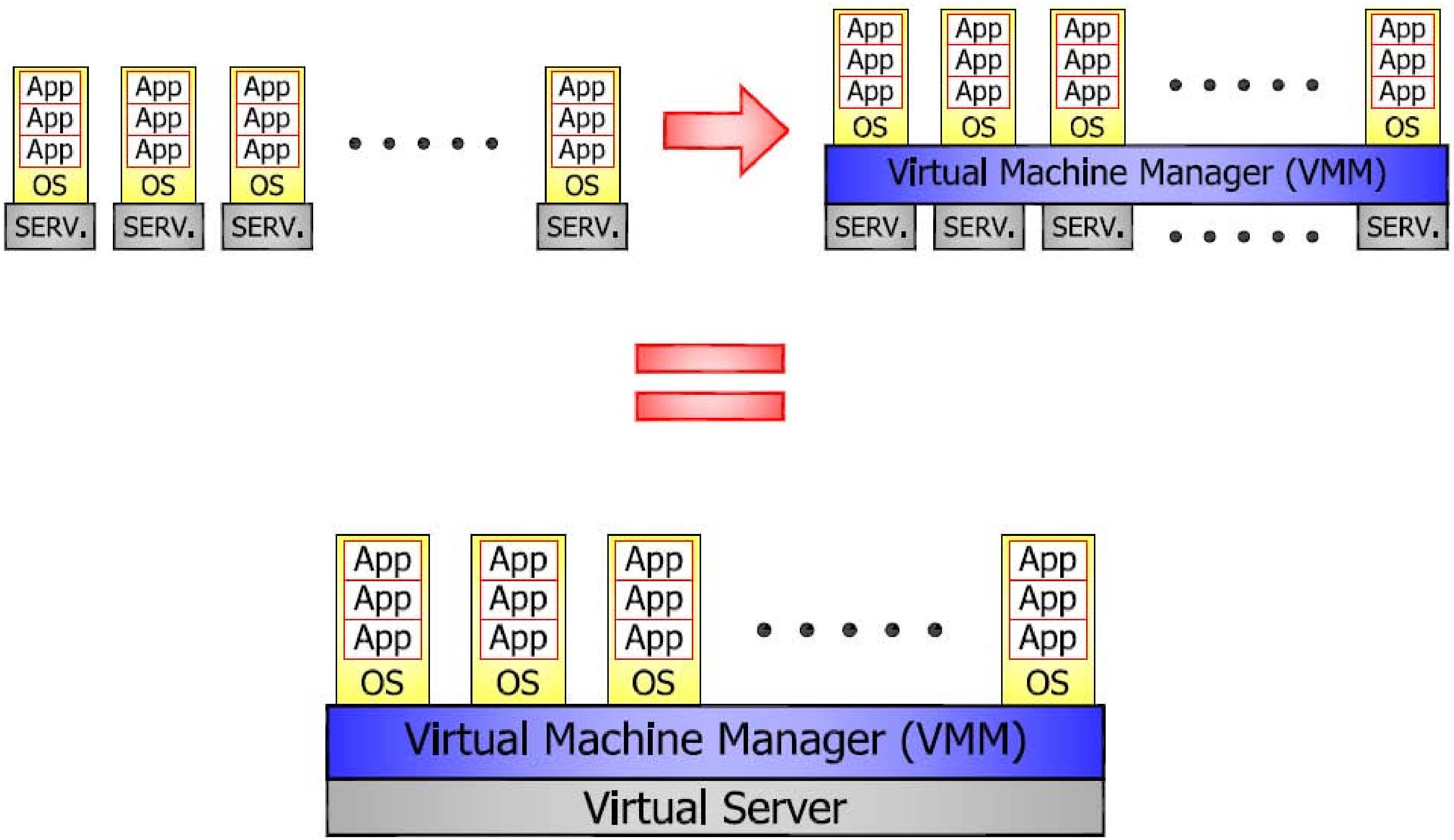
IT Equipment – Servers

Some aspects to consider with regards to server energy efficiency:

- Virtualization
- Server And Component Power
- Energy Efficient Power Supplies
- Utilize Power Management Features

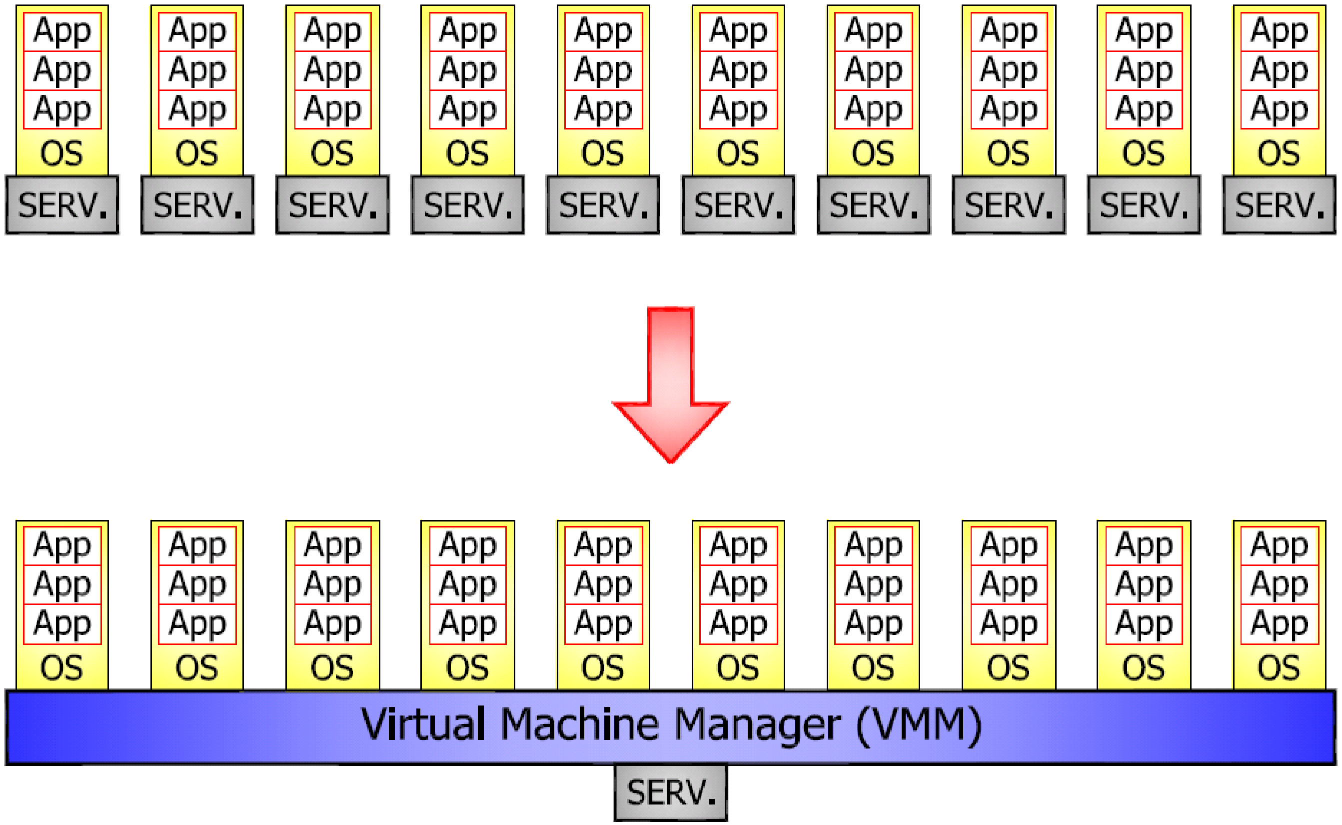
Virtualization

Server Management Software that allows applications to seamlessly share server resources (even if on separate operating systems).



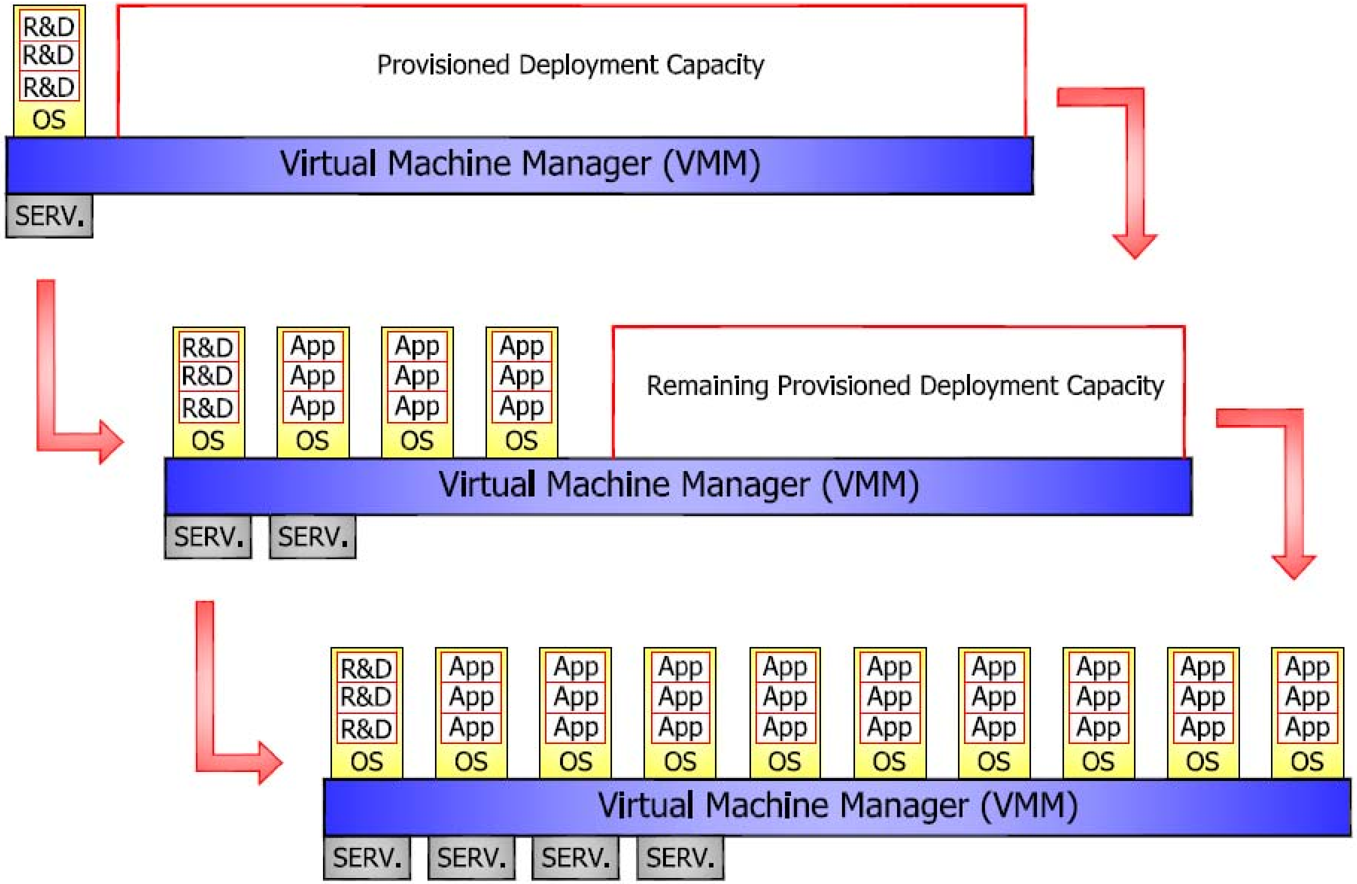
Virtualization: Facilitates Hardware Consolidation

Server consolidation can be 10:1 in many cases.



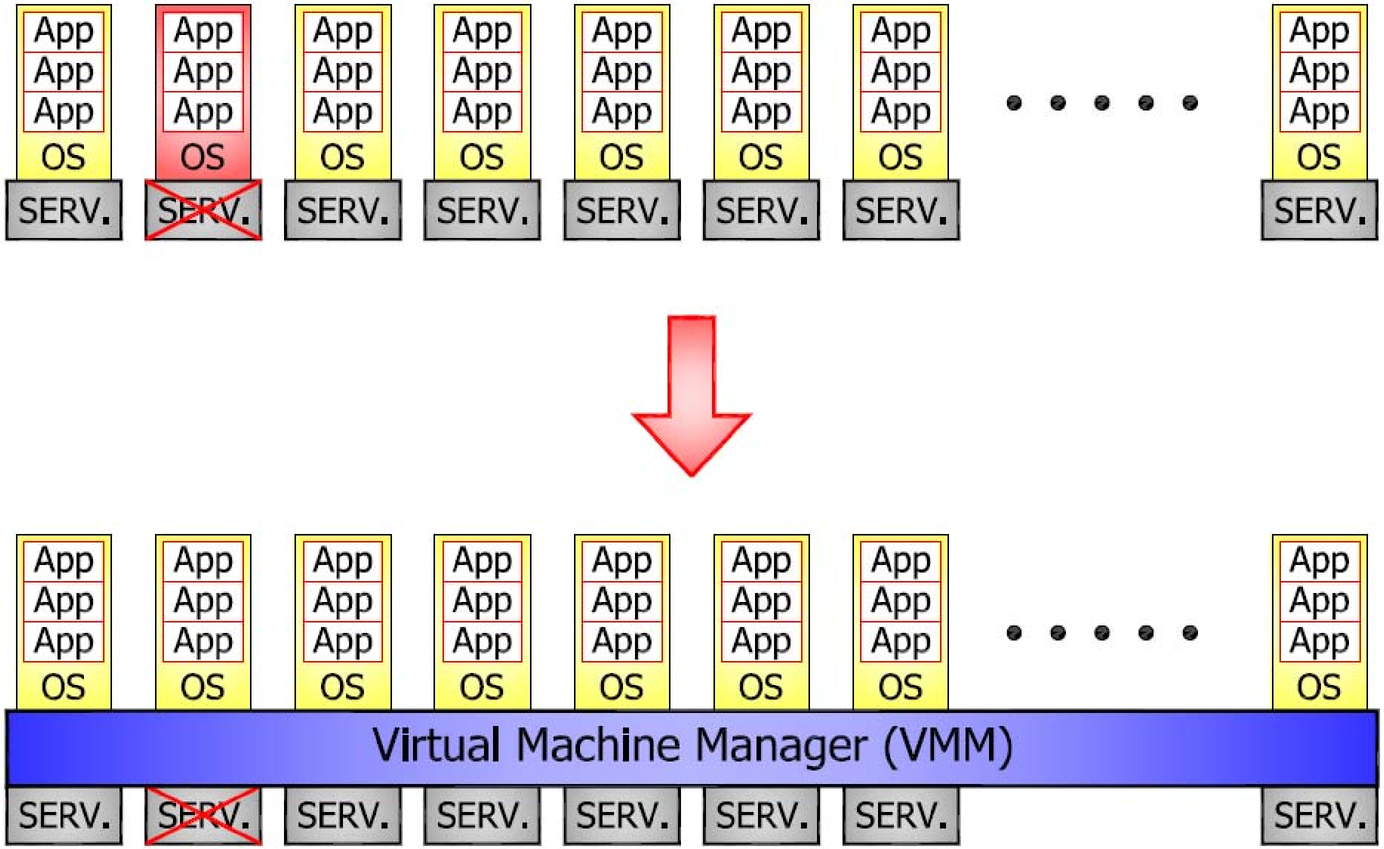
Virtualization: Facilitates Scalable / Phased Deployment

Enables rapid deployment after R&D, reducing no. of idle staged servers.



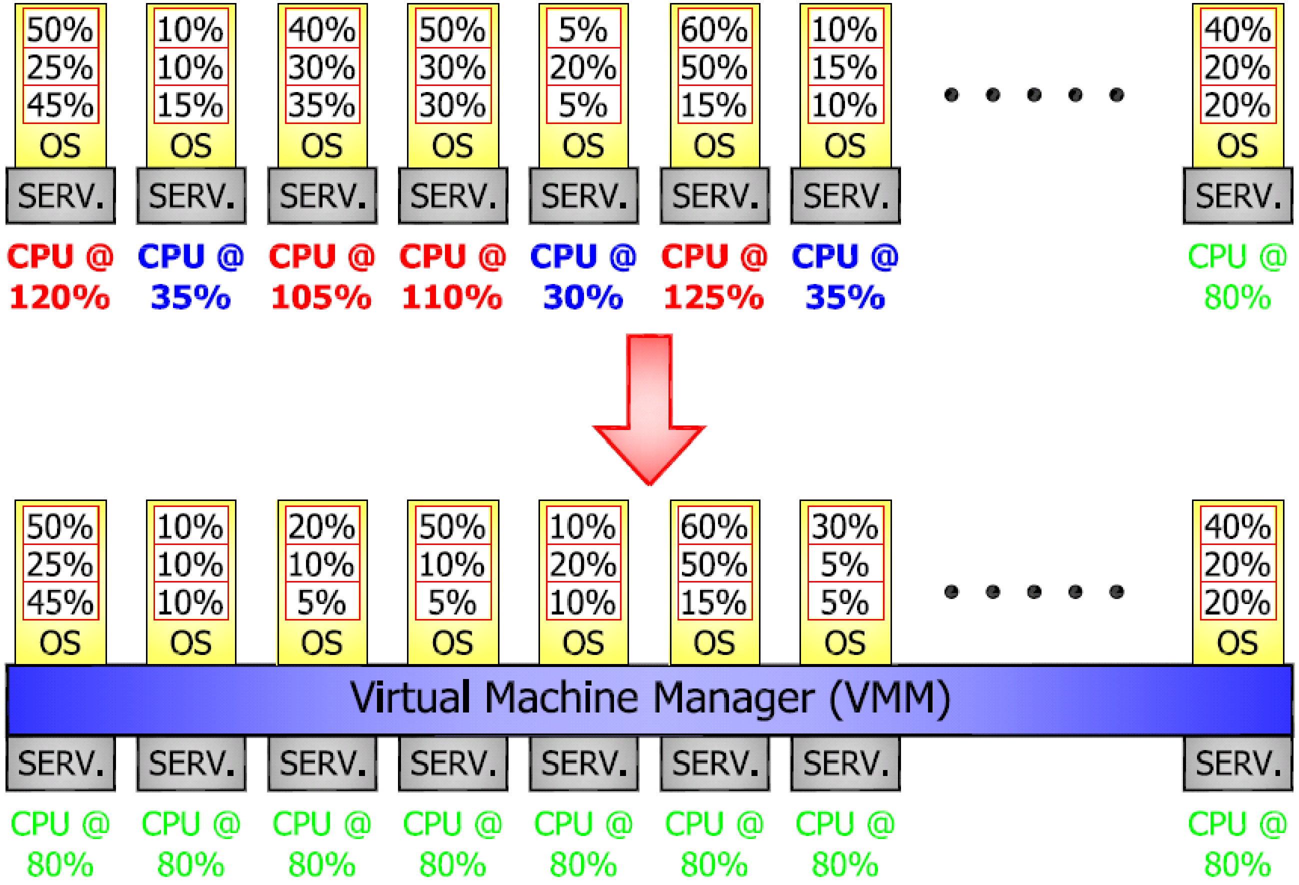
Virtualization: Facilitates Self Healing; Uninterrupted Applications

Spare servers can support hardware failures on multiple server types.

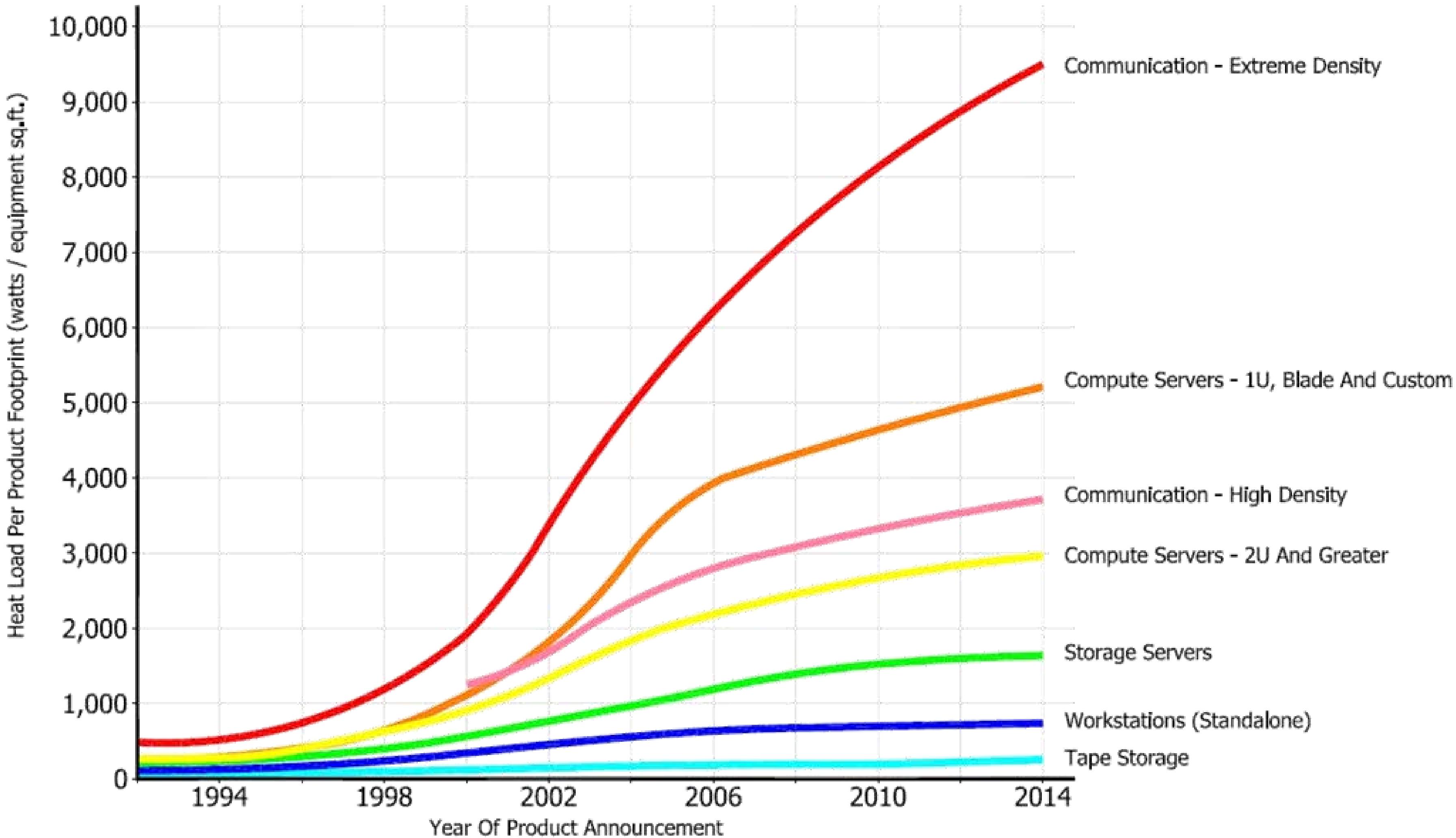


Virtualization: Facilitates Workload Provisioning

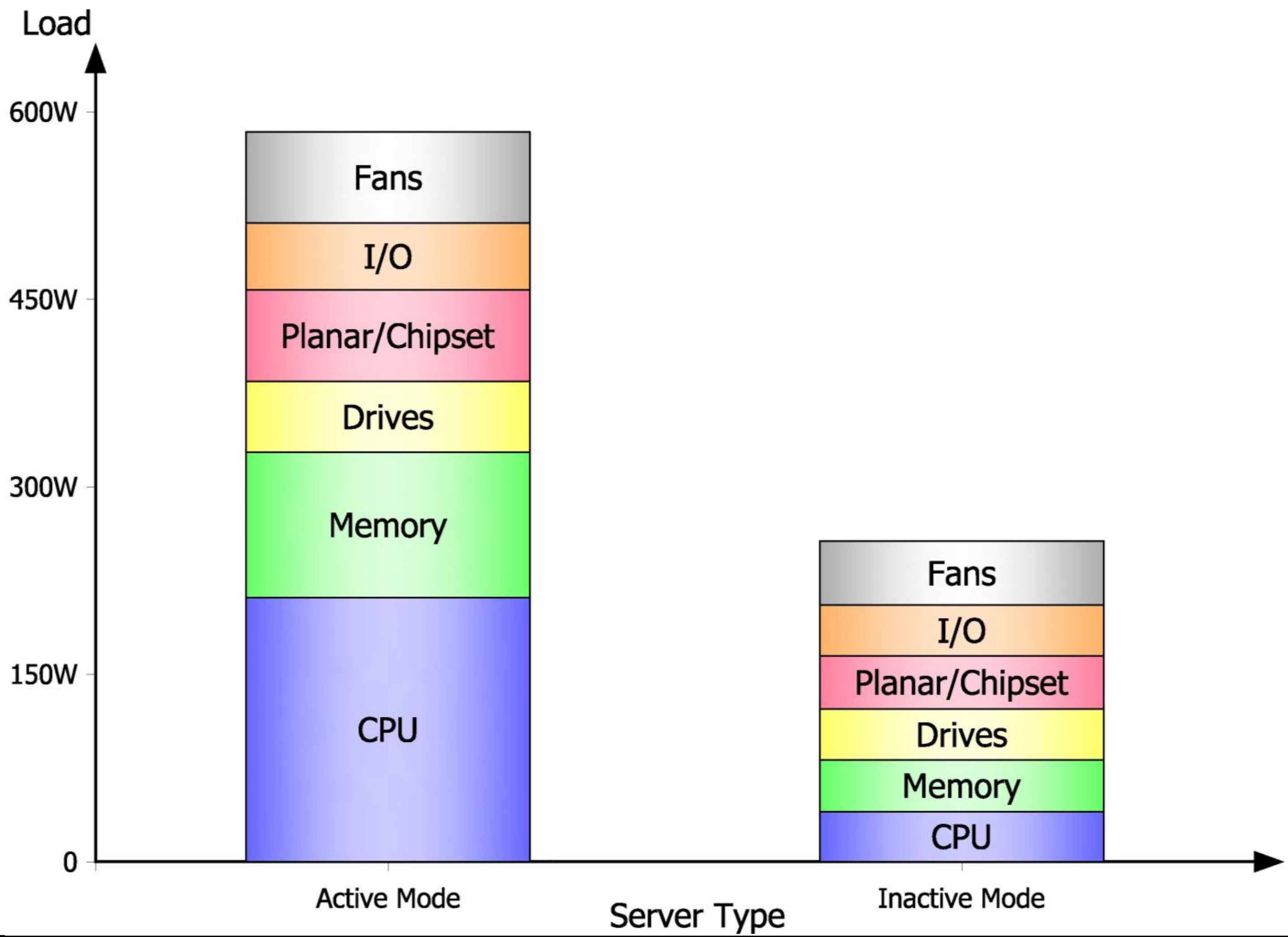
Load-sharing can distribute load from many applications.



Server and Component Power Usage Trends



IT Energy Usage In Servers



IT Energy Use Patterns: Servers

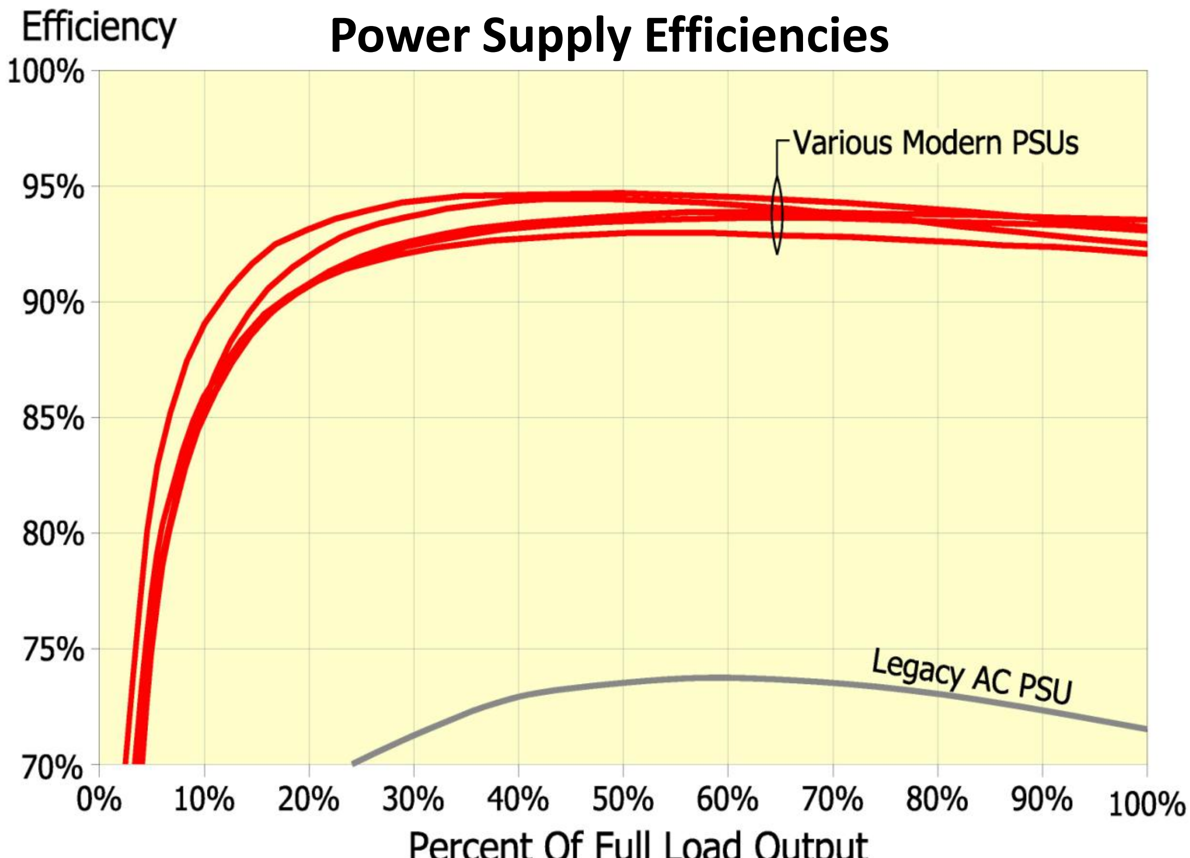
Load		Operations per Second	Power Consumption in Watts	Operations per Watt
Target	Actual			
100%	99.2%	308,022	269	1145
80%	80.0%	248,304	256	969
60%	60.1%	186,594	238	784
40%	39.9%	123,805	215	575
20%	20.1%	62,364	189	329
10%	10.0%	31,049	174	178
0% (Active but Idle)		**0**	**160**	**0**

Active–Idle servers consume as much as 50-60% of full load power

Source: SpecPower Benchmark Published Results

Power Supply Units (PSU)

PSUs are most efficient in the mid-range of their performance curves.
PSU redundancy decreases loading on each unit, lowering efficiency.



Source: The Green Grid

Electronic Component Power Dissipation (Example Processor)

An increase in processor operating frequency not only increases system performance, but also increases the processor power dissipation.

The relationship between frequency and power is generalized in the following equation:

$$P=CV^2F$$

where: P = power, C = capacitance, V = voltage, F = frequency

From this equation it is evident that power increases linearly with frequency and with the square of voltage. Power saving technologies manipulate:

- Frequency via clock modulations
- Voltage
- Capacitance through transistor characteristics (aka process technologies)

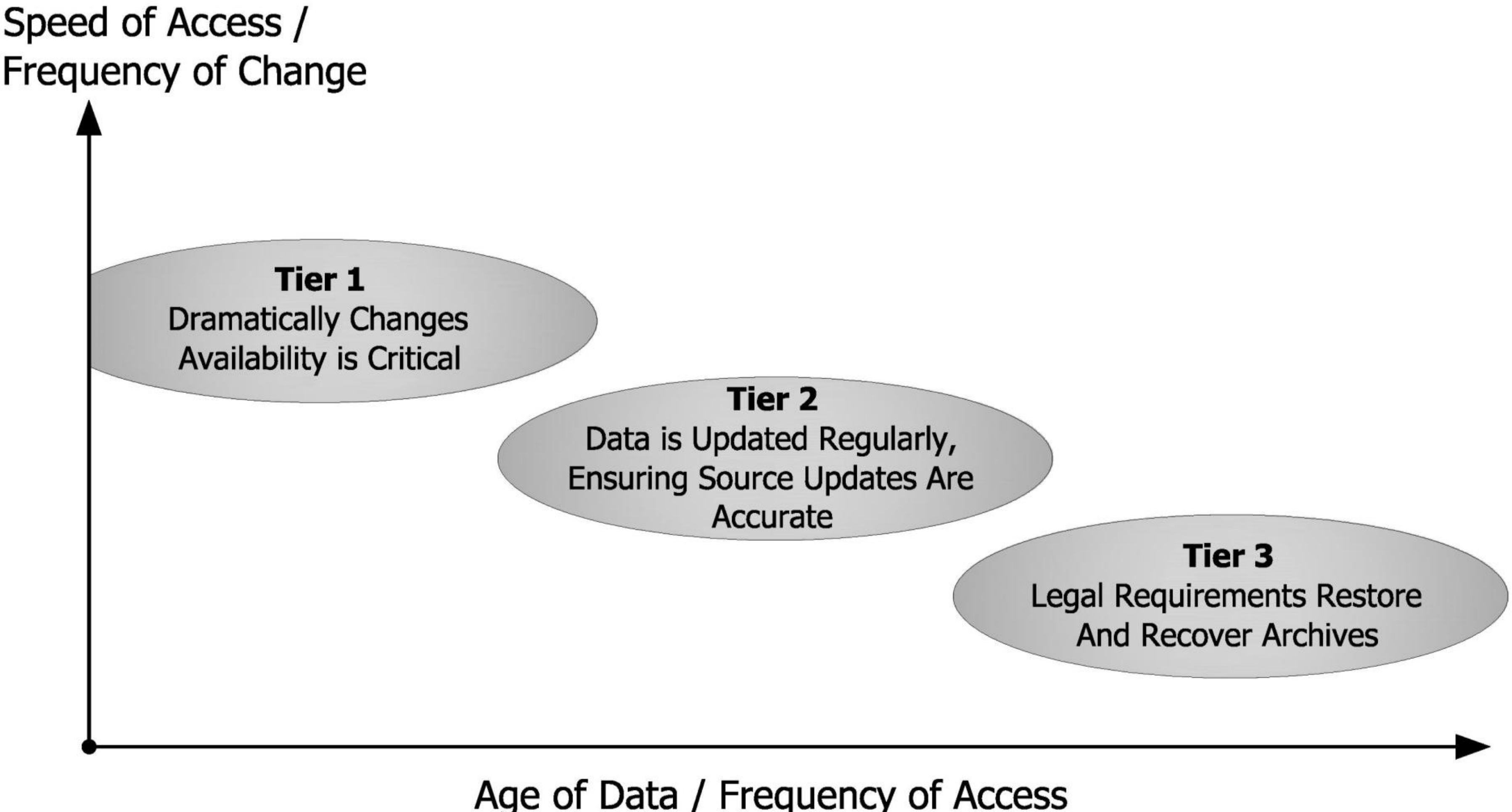
OUTPUT REQUIREMENTS (i.e. SLAs) DRIVE BOTH COMPONENT SELECTION AND SAVINGS OPPORTUNITIES

IT Equipment – Storage

Some aspects to consider with regards to storage energy efficiency:

- De-duplication
- Thin Provisioning
- Utilize Tiered Storage
- Consolidate Platforms
- “Pay As You Grow” Configuration Flexibility
- Performance Management
- Managed Capacity

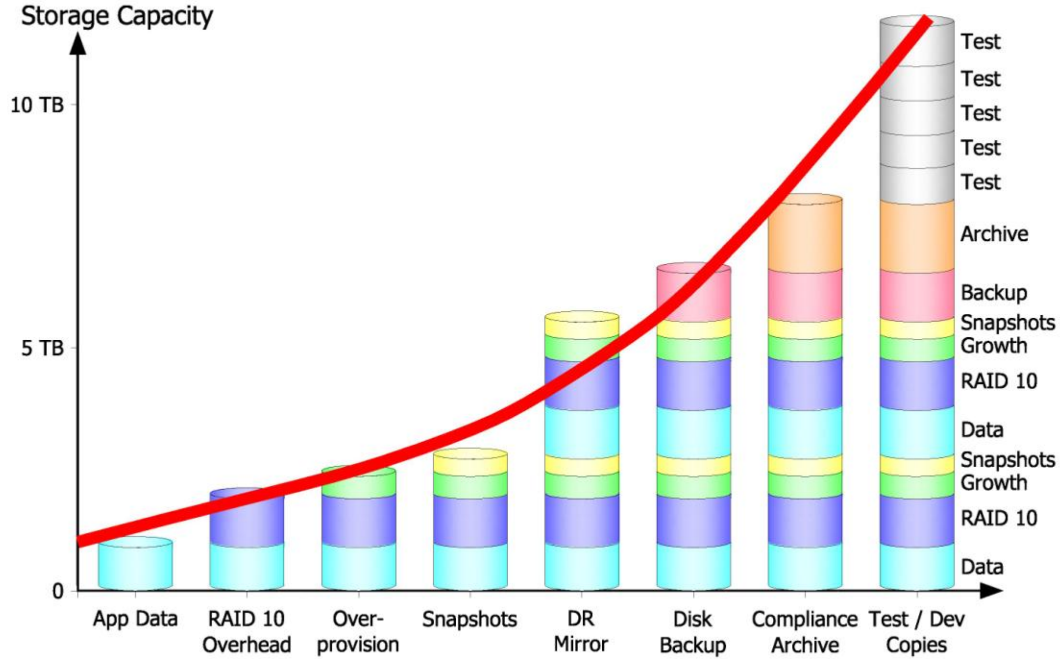
Storage Hierarchy



Source: Intel

Storage Systems- Energy Use

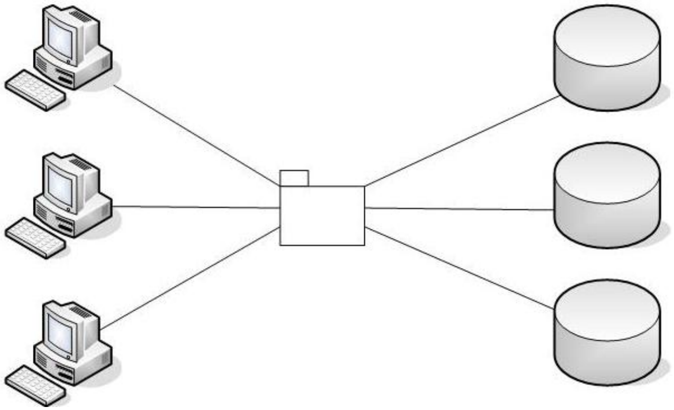
Storage requirements and power consumption increase ROUGHLY PROPORTIONALLY as multiple file copies are created for different purposes, including redundancy. Storage redundancy needs to be rationalized and right-sized to AVOID rapid scale-up in size and power consumption.



Results Of Redundancy

Source: SNIA

Networking



Considerations when provisioning:

- Security, Availability and Bandwidth

Identify and remove network bottlenecks

- Otherwise the rest of the IT may suffer inefficiencies

Identify unused network equipment

Consolidate over allocated ports

Bandwidth tradeoff

IT Power and Cooling Load Estimation Tools

Predicting IT loads

- Oversizing, at least initially, is common
- Implement modular and scalable approaches

IT loads can be controlled

- Power supply options
- Server efficiency
- Software efficiency (Virtualization, Massive Array of Idle Disks [MAID])
- Redundancy (Redundant Array of Independent Disks [RAID]) and back-up power
- Low power modes

IT Energy Audits - DC Pro Profile And Assessment Process

IT Energy Assessment Process		
Step	Assessment Area	Assessment Process
Step 1	Energy Management	Describe extent of energy management & governance at data center
Step 2	Workload	Describe IT workload
Step 3	Resources	Summarize inventory of IT resources
Step 4	Baseline	Establish baseline of IT energy load
Step 5	Current vs. Best Practices	Assess data center use of industry best practices
Step 6	Potential Savings	List possible actions and their potential savings
Step 7	Data Center Readiness	Self-assessment of DC readiness to implement

IT Energy Audits - Use of Metrics & Measurements

	Metrics	Measurements / Readings	Recommended Method
A	Total IT Energy Load	Total Energy Consumed (KWH)	Measured or Derived at Output of PDU
B	Operating Period	Hours (hrs)	Corresponding Timeframe w/ “A”
C	Average IT Load	Average Real Power (KW)	“A” / “B”
D	Peak IT Load	Average Real Power (KW)	Total Of PDU Outputs at Corresponding Times
E	Average Power Density	KW per Square Feet	“C” / “B”
F	Peak Power Density	KW per Square Feet	“D” / “B”
G	Rack Power Density	KW per Rack Square Feet	“C” / Total Rack Footprint in KW
H	Data Center Productivity	Overall DC Productivity	Chart

Power Management At A System Level - Energy Policies

The key to reducing power : Turn unused circuits off; **but**, guarantee SLA response requirements

(System) Power management is dependent on resume-to-continued-operation latencies and meeting SLAs.

- Subsystem power management relies on autonomous hardware and operating system power management based on a user's power policy
- System and rack level management relies on equipment managers (utilities) in conjunction with hardware and software autonomous functions

Effective controls require the IT manger to develop an energy activity policy that meets SLA requirements and can be programmed into power management systems.

Energy Policies drive autonomous rack & system power management

Client Consolidation? Thin Clients - Apples and Oranges

Thin Client configuration is a computing model

- Security
- Media distribution
- Compute services or capability resident at the host only
- Requires a dedicated, robust, & always available computing infrastructure

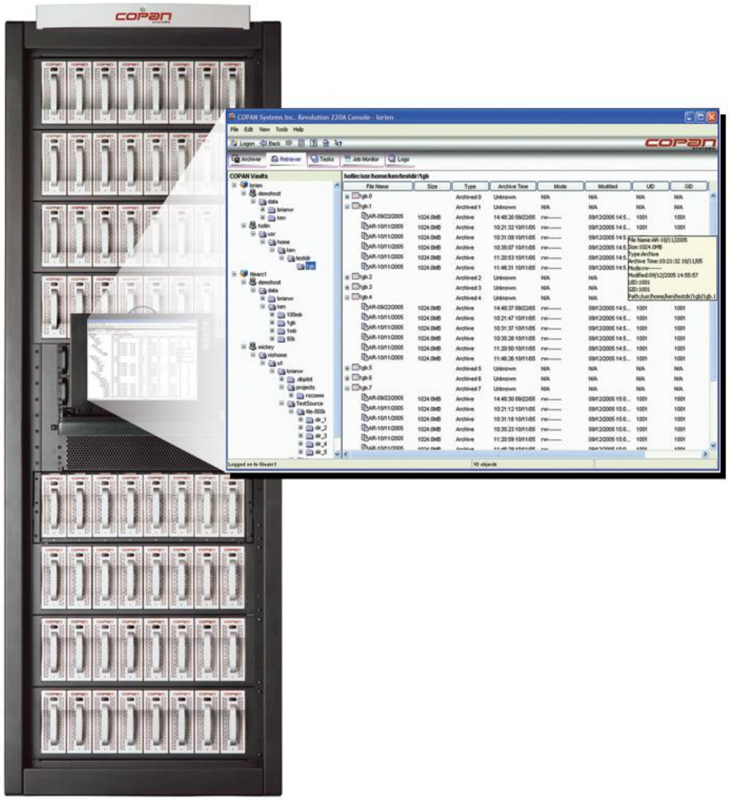
Thin clients shifts energy and compute focus onto the network & servers.

- No mobility. Different computing model
- Network bandwidth and load increases
- Limited/no independent computing
- Dependent on availability and efficiencies of network and servers

Massive Array of Idle Disks (MAID)

MAID is designed for Write Once, Read Occasionally (WORO) applications.

In a MAID, each drive is only spun up on demand as needed to access the data stored on that drive.



Decommissioning

Some decommissioning goals include:

- Regular inventory and monitoring
- Offline idle or unassigned equipment
- Identify low utilized hardware- consolidate
- Remove leftover hardware from unfinished projects
- Retire legacy hardware especially following refresh

PHYSICALLY RETIRE AN INEFFICIENT SYSTEM.

DO NOT PUSH THE PROBLEM ELSEWHERE.

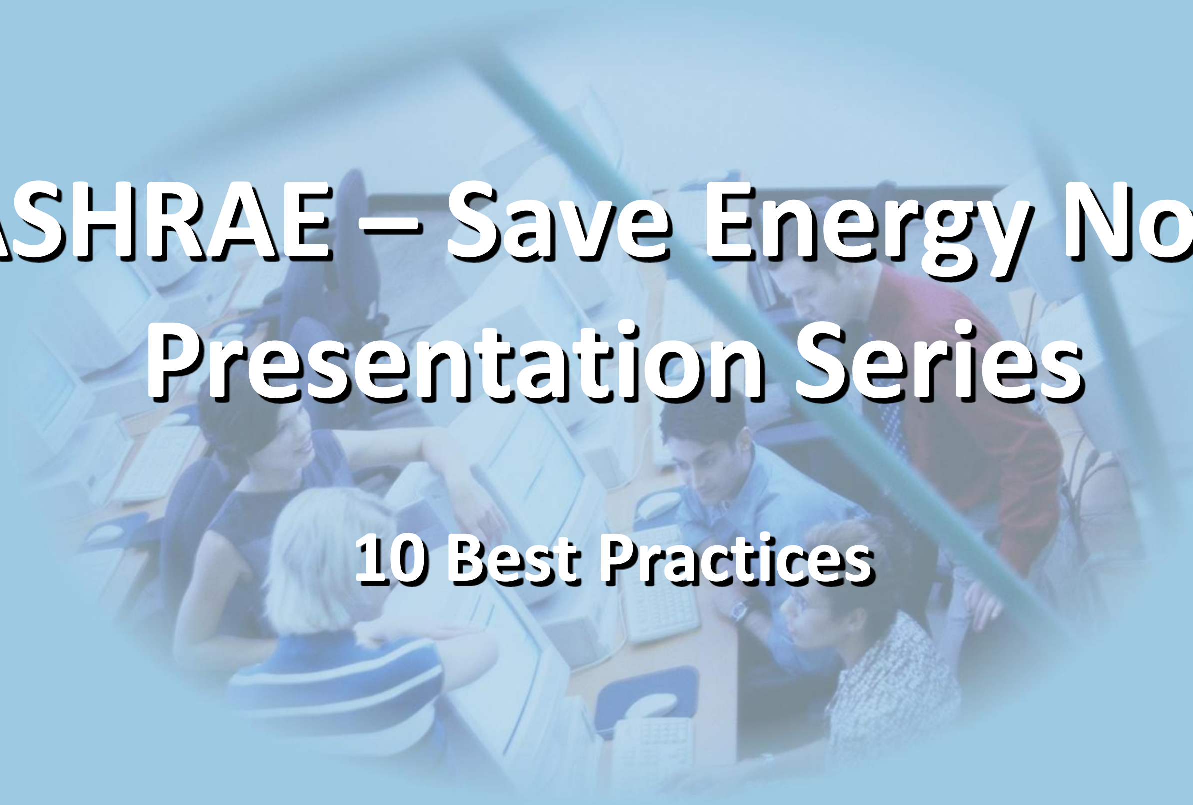
Key Takeaways

The single largest component of energy usage in data centers is that used by the IT equipment itself.

Steps that can be taken to optimize the IT equipment energy include:

- Design the IT environment to the expanded ASHRAE Thermal Guidelines
- Use Thermal Reports to establish the true heat load from servers
- Develop an IT Provisioning Strategy
- Plan data collection to better manage energy consumption
- Consider virtualization to optimize hardware usage / reliability
- Use Energy Policies to drive autonomous rack & system power management

ASHRAE – Save Energy Now Presentation Series



10 Best Practices

10 Best Practices

#	Best Practice
1	Inlet air is most important for IT equipment
2	Implement Cold Aisle/Hot Aisle – Separate Cold And Hot Air
3	Utilize Outside Environment To More Directly Cool The Data Center
4	Deploy Energy Efficient Power Distribution Components
5	Consider Localized Cooling For High Density Areas
6	Measure, Analyze and Benchmark Datacom Facility Efficiency
7	Investigate Each Cooling Component For Improved Efficiency
8	Improve Air Conditioning
9	Utilize Manufacturer's Measured Power / Thermal Data to Optimize Layout of Data Center
10	Virtualize and Consolidate

Resources - ASHRAE TC9.9

http://tc99.ashraetcs.org/

Datacom Series

- Thermal Guidelines for Data Processing Equipment
- Datacom Equipment Power Trends and Cooling Applications
- Design Considerations for Datacom Equipment Centers
- Liquid Cooling Design Considerations for Data and Communications Centers
- Structural and Vibration Guidelines for Datacom Equipment Centers
- Best Practice for Datacom Facility for Energy Efficiency
- High Density Data Centers:Case Studies and other Considerations
- Particulate and Gaseous Contamination in Datacom Environments

Purchases of more than 10 books – 50% off
Purchases of more than 100 books – 60% off

Resources - Green Grid

http://www.thegreengrid.org

The Green Grid, 2007, “Green Grid Metrics: Describing Data Center Power Efficiency,” Technical Committee White Paper, http://www.thegreengrid.org/downloads/Green_Grid_Metrics_WP.pdf .

- The Green Grid, 2009, “Data Center Baseline Study Report”
- The Green Grid, 2009, “Free Cooling Tool”
- The Green Grid, 2009, “Data Center Design Guide”
- The Green Grid, 2009, “The Green Grid Data Center Power Efficiency Metric:PUE & DCiE”
- The Green Grid, 2009, “Proxy Proposal for Measuring Data Center Productivity”
- The Green Grid, 2009, “Fundamentals of Data Center Power and Cooling”
- The Green Grid, 2009, “Quantative Analysis of Power Distribution Analysis”
- The Green Grid, 2009, “Virtualize for Data Center Efficiency”
- The Green Grid, 2009, “Lower Humidity in the Data Center”

Resources - LBNL

http://hightech.lbl.gov/DCTraining/tools.html

http://hightech.lbl.gov/dc-benchmarking-results.html

LBNL, 2003, LBNL, http://datacenters.lbl.gov/CaseStudies.html

LBNL 2007, Benchmarking: Data Centers – Charts. http://hightech.lbl.gov/benchmarking-dc-charts.html Lawrence Berkeley National Lab.

LBNL 2007, Data Center Economizer Contamination and Humidity Study. Lawrence Berkeley National Lab.

LBNL 2007, Self Benchmarking Guide for Data Center Energy Performance, Version 1.0., http://hightech.lbl.gov/documents/DATA_CENTERS/Self_benchmarking_guide-2.pdf, Lawrence Berkeley National Lab.

LBNL 2007, DC Power for Improved Data Center Efficiency, Lawrence Berkeley National Lab. January 2007

10 Best Practices

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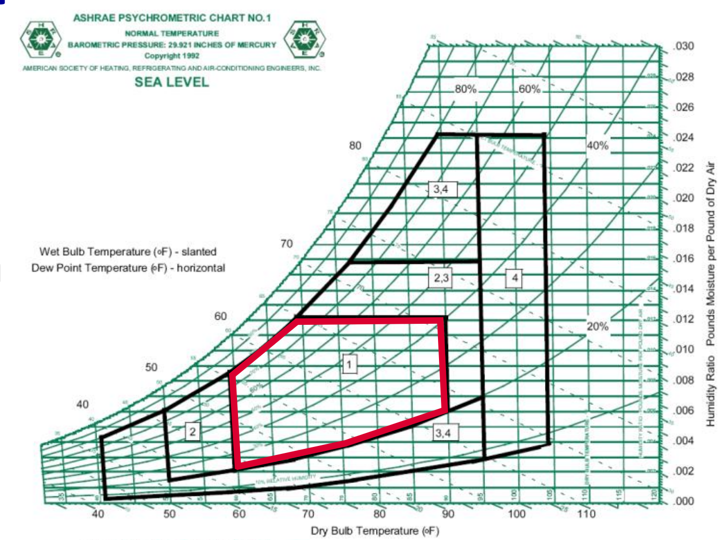
8	Improve Air Conditioning
9	Utilize Manufacturer's Measured Power / Thermal Data to Optimize Layout of Data Center
10	Virtualize and Consolidate

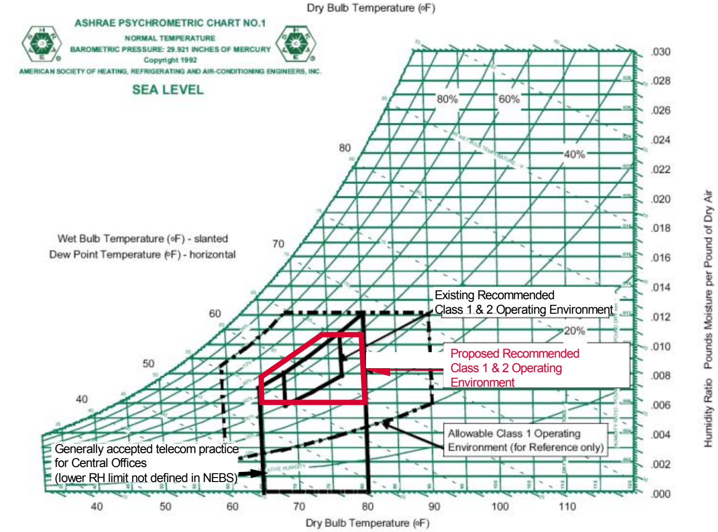
Supplemental Material

#1 Best Practice : Inlet air is most important for IT equipment

The allowable envelope are those boundaries where IT manufacturers test their equipment in order to verify that the equipment will function within those limits. This is not a statement of reliability but one of functionality of the IT equipment

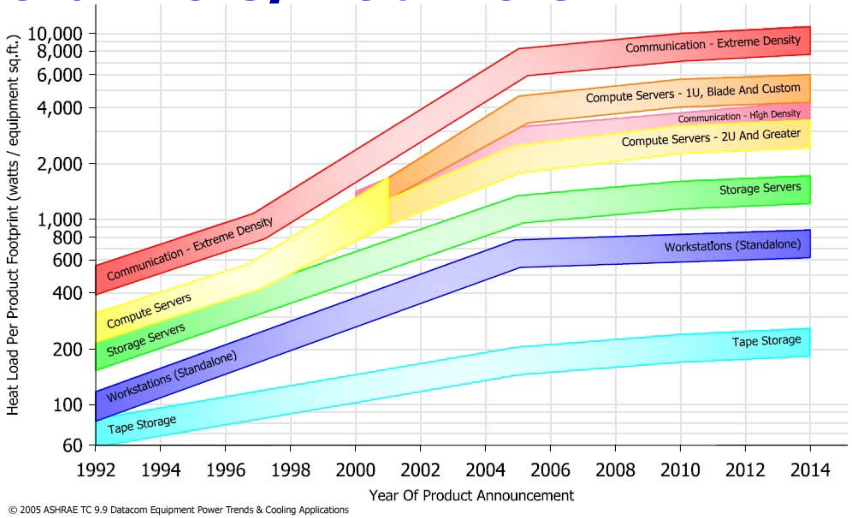
The recommended envelope is a statement on reliability. For extended periods of time, the IT manufacturers recommend that data center operators maintain their environment within the recommended envelope





#2 Best Practice : Implement Cold Aisle/Hot Aisle – Separate Cold And Hot Air

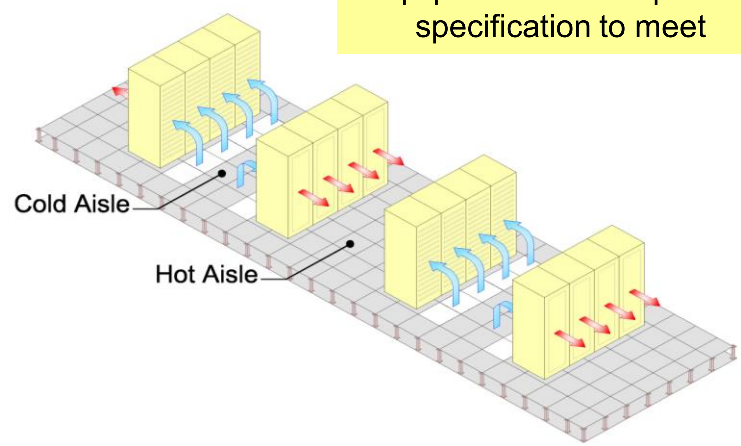
IT Equipment Power Trends continue to rise



IT Equipment air temperature inlet is what is most important to control

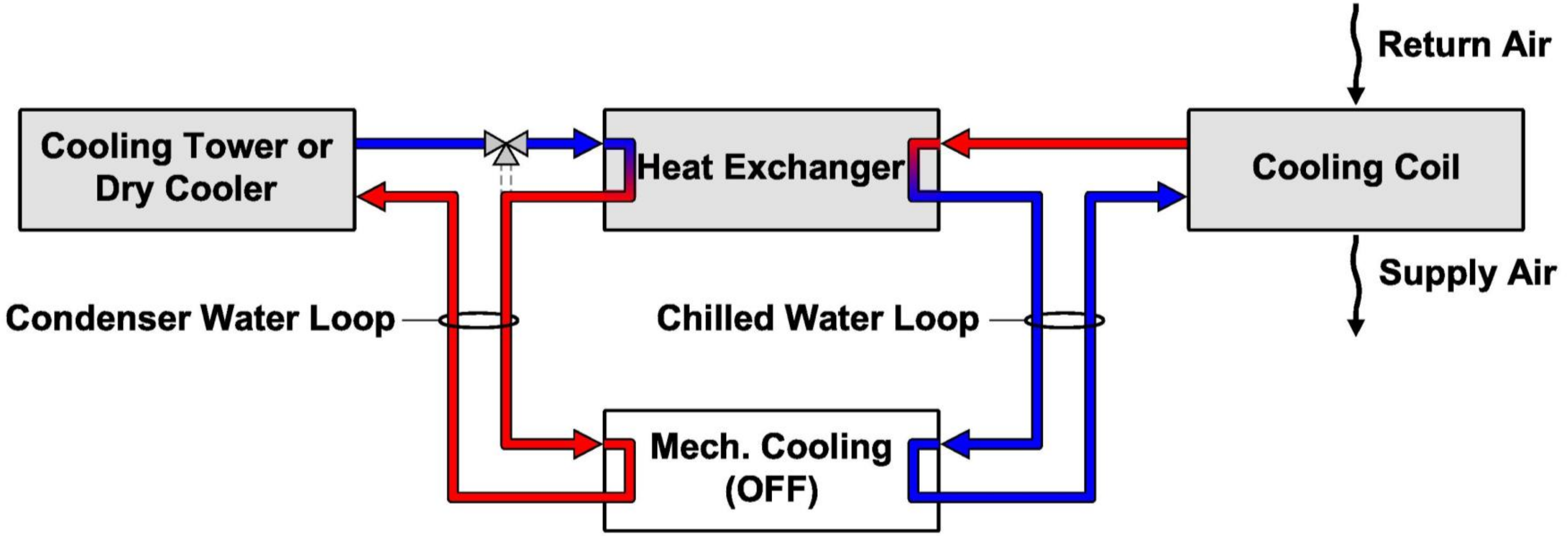
__Air Inlet__ to Datacom Equipment **is** the important specification to meet

Install blanking panels



#3 Best Practice : Utilize Outside Environment To More Directly Cool The Data Center

Water-Side Economizers



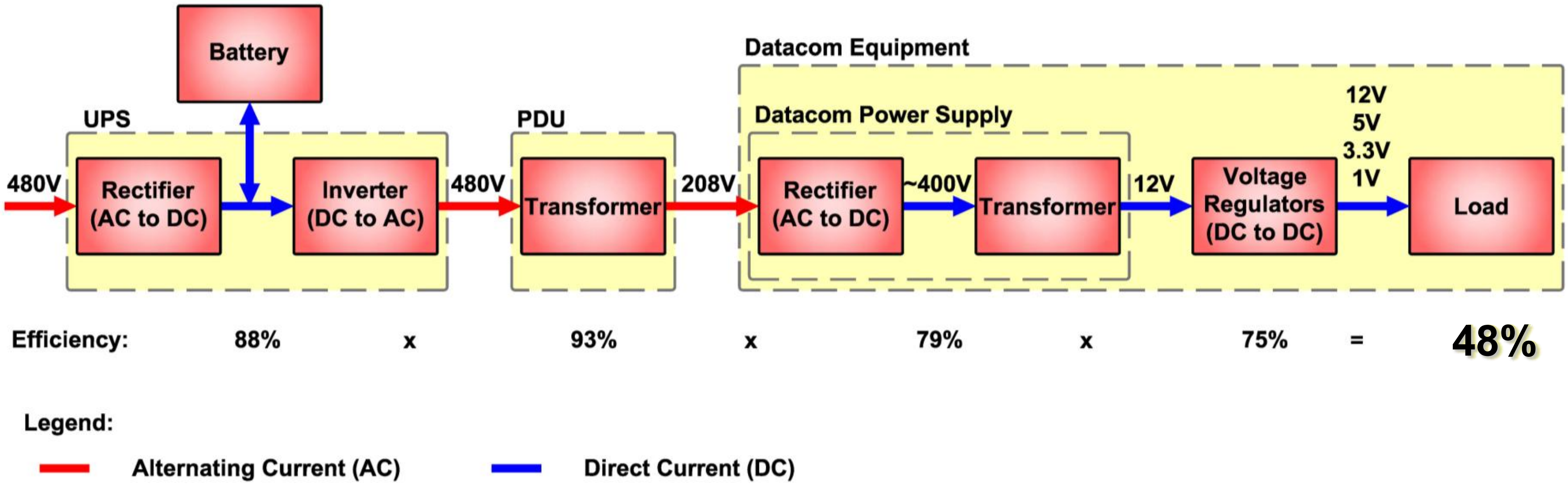
Water-Side Economizer (Indirect)

Mechanical Cooling Off

#4 Best Practice: Deploy Energy Efficient Power Distribution Components

The primary electrical distribution losses for data centers were:

- An average 8% loss for Uninterruptible Power Supply (UPS) equipment.
- Electrical distribution losses such as transformers also made up some component of the 11% of ‘Other Losses’.



#5 Best Practice: Consider Localized Cooling For High Density Areas

Traditional Data Center General Guidelines

- Local cooling capacity shortfalls can cause problems
- The global cooling supply must be greater then the global cooling needs
- Recirculation of hot air can be managed based on airflow and temperature measurements

Non-Traditional Data Center General Guidelines

- Efficient design is key to support High Density
- Localized cooling can provide for high density IT equipment in a low or high density capable room
- Redundant capacity must be considered in non-traditional designs

#6 Best Practice: Measure, Analyze and Benchmark Datacom Facility Efficiency

Data Center Infrastructure Efficiency (DCiE)

$$DCiE = \frac{IT\ Equipment\ Power}{Total\ Facility\ Power}\ (The\ Green\ Grid, 2007)$$

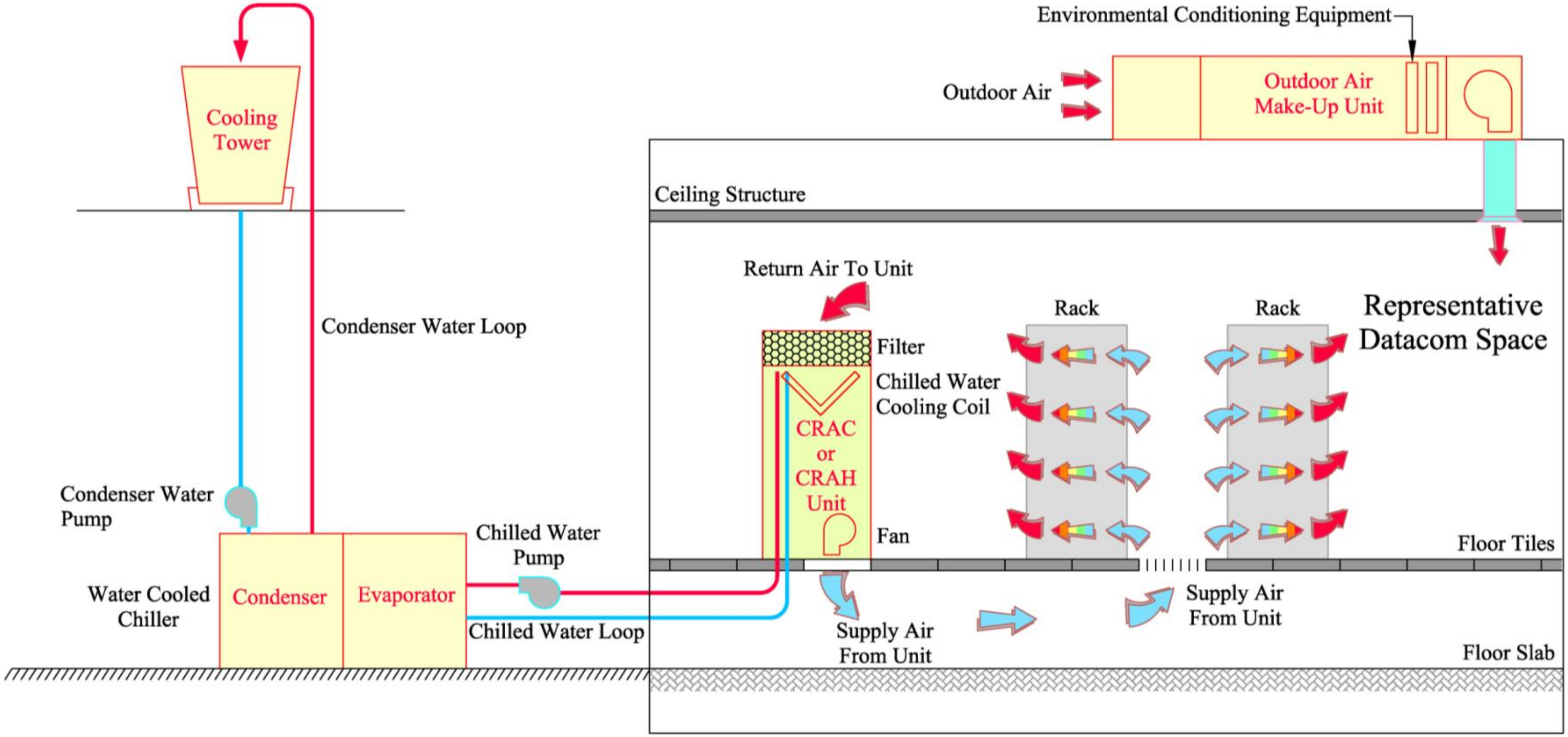
Power Usage Effectiveness (PUE)

$$PUE = \frac{Total\ Facility\ Power}{IT\ Equipment\ Power}\ (The\ Green\ Grid, 2007)$$

Cooling Plant Efficiency = IT Load (kW Output) / Cooling Plant kW Input

#7 Best Practice: Investigate Each Cooling Component For Improved Efficiency Of The Cooling System

Typical Cooling System



There are energy saving opportunities in each piece to the Cooling System

#8 Best Practice: Improve Air Conditioning

The Important Measurements for Evaluating Data Center Air-conditioning are: POWER, AIRFLOW and TEMPERATURE

Power – trend average and peak loads

Airflow – proves the cooling is being delivered where intended

Temperature – is the ultimate measure of cooling performance

#9 Best Practice: Utilize Manufacturer's Measured Power / Thermal Data to Optimize Layout of Data Center

Nameplate Data versus ASHRAE Equipment Thermal Report

- Datacom equipment manufacturers' nameplate data has a regulatory safety focus & the values are not an accurate reflection of heat release.
- ASHRAE's Thermal Guidelines for Data Processing Environments requires the datacom equipment manufacturer to publish the following for each product:
  - Steady state heat release numbers in watts
  - Maximum & nominal airflow quantity & pattern under normal operating conditions
  - Variations of above based on specific equipment configurations via predictive algorithms.
- The information is to be listed in the form of a Equipment Thermal Report.

#10 Best Practice: Virtualize and Consolidate

Stop over-provisioning servers / storage / network

Kill dead servers / storage

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Data Center Efficiency Programs To Support Federal Projects

Federal Data Center Efficiency Programs:

- DOE Industrial Technologies Program
- DOE Federal Energy Management Program
- GSA
- Energy Star Products
- EPA Energy Star Buildings

DOE Industrial Technologies Program

Working to improve the energy efficiency of U.S. industry

U.S. industry consumes 32 quadrillion Btu per year - almost 1/3 of all energy used in the nation

Partnerships with energy-intensive industries are key to ITP's success:

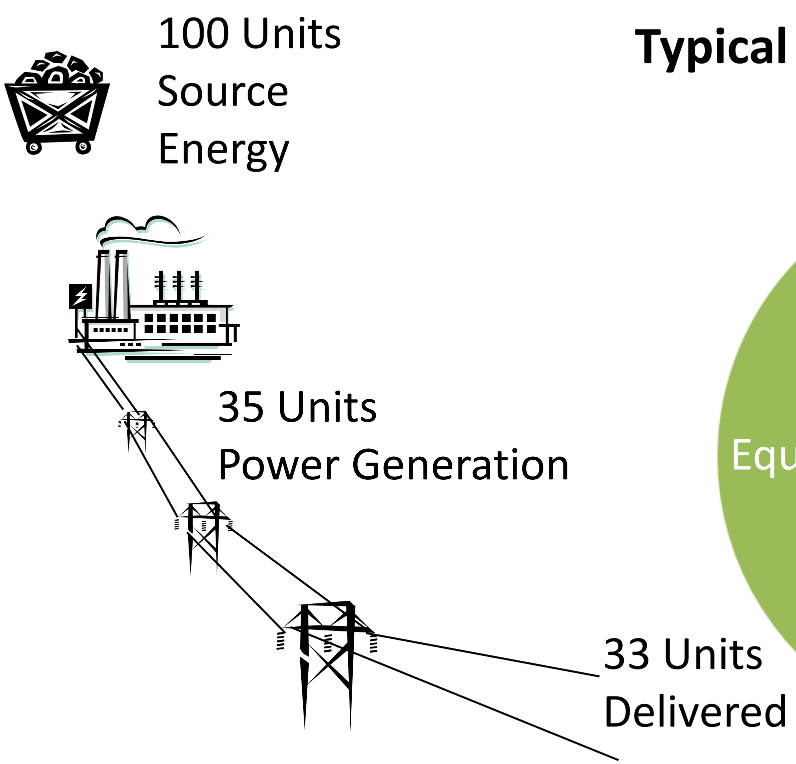
- 5 quads of energy savings, 86 MMTCE reduction

Save Energy Now is working to reduce industrial energy intensity 25% by 2017

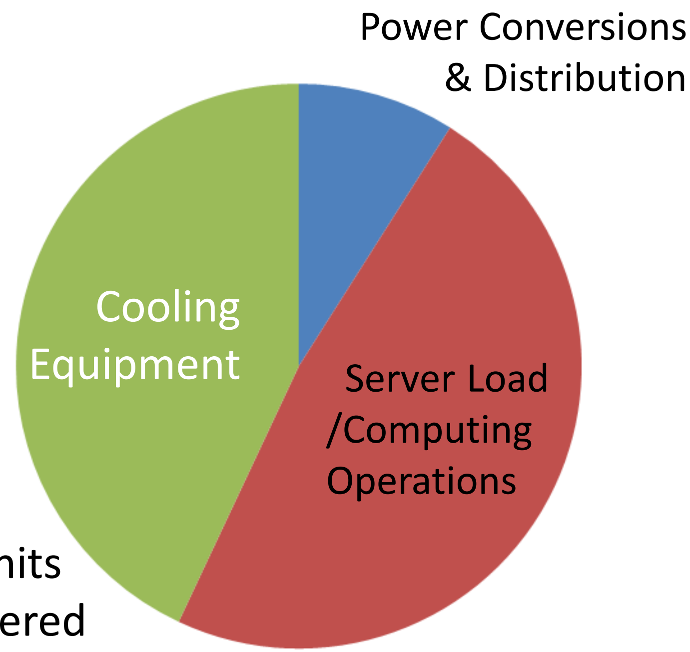
Data Centers are Information Factories with a growing appetite for energy

Data Center Energy Efficiency = 15% (or less)

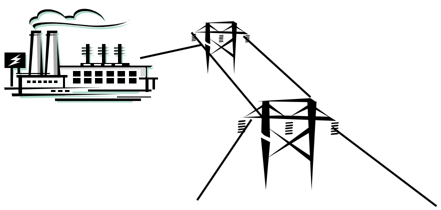
(Energy Efficiency = Useful computation / Total Source Energy)



Typical Data Center Energy End Use



Energy Efficiency Opportunities



Server innovation
Virtualization
High efficiency power supplies
Load management

Better air management
Move to liquid cooling
Optimized chilled-water plants
Use of free cooling
Heat recovery

Power Conversion & Distribution

Server Load/ Computing Operations

Cooling Equipment

High voltage distribution
High efficiency UPS systems
Efficient redundancy strategies
Use of DC power

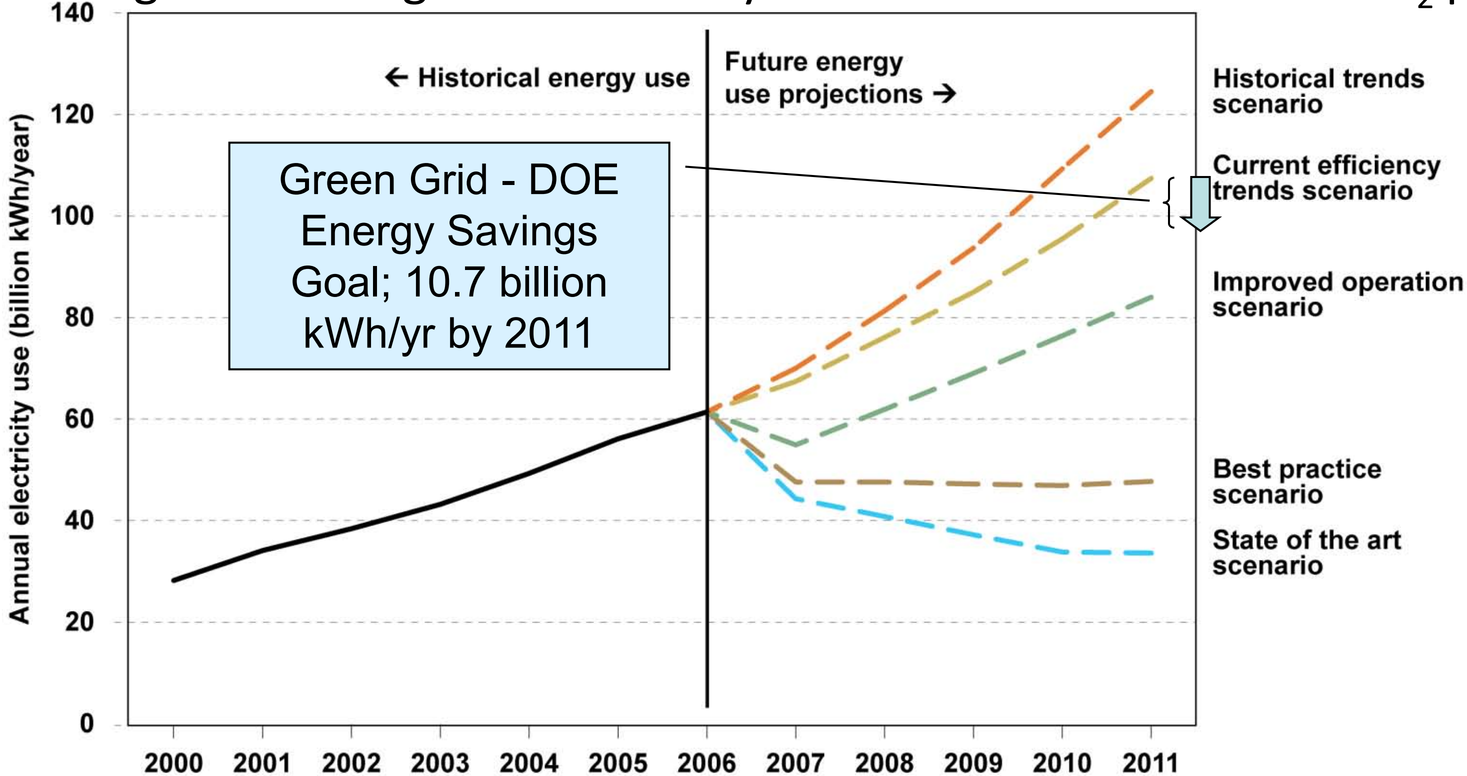
Alternative Power Generation

On-site generation
Including fuel cells and renewable sources
CHP applications
(Waste heat for cooling)

DOE-Green Grid Goal for Energy Savings

2011 goal is 10% energy savings overall in U.S. data center

- 10.7 billion kWh
- Equivalent to electricity consumed by 1 million typical U.S. households
- Reduces greenhouse gas emissions by 6.5 million metrics tons of CO_2 per year



DOE Save Energy Now Data Center Program

Major Program Elements:

- Develop and test “DC Pro” Software
  - http://dcpro.ppc.com/
- Create consensus metrics
- Create and publicize Save Energy Now case studies
- Create best practice information and a training curriculum
- Develop Certified Professional program for Data Centers
- Create guidelines for “Best-in-Class” data centers
- Create and implement a collaborative research program with industry

By the end of 2011

Products

DC Pro tool

- **Assessment protocols and tools**
- **Training curriculum**
- **Case studies**
- **Best practices**
- **Best-in-Class guidelines**
- **Technology R&D and demonstrations**

Market Delivery

- **200 Qualified Specialists**
- **Suppliers**
- **Engineering firms**
- **Utilities**
- **Associations and technical Organizations**

Data Center Results

- **10 billion kWh per year saved**
- **3,000 people trained on tools and assessment protocols**
- **1,500 data centers improve energy efficiency > 25%**
- **200 data centers improve energy efficiency >50%**

DOE DC Pro Tool Suite

High-Level On-Line Profiling (and Tracking) Tool

- Overall efficiency (DCiE)
- End-use breakout
- Potential areas for energy efficiency improvement
- Overall energy use reduction potential

In-Depth Excel Assessment Tools → Savings

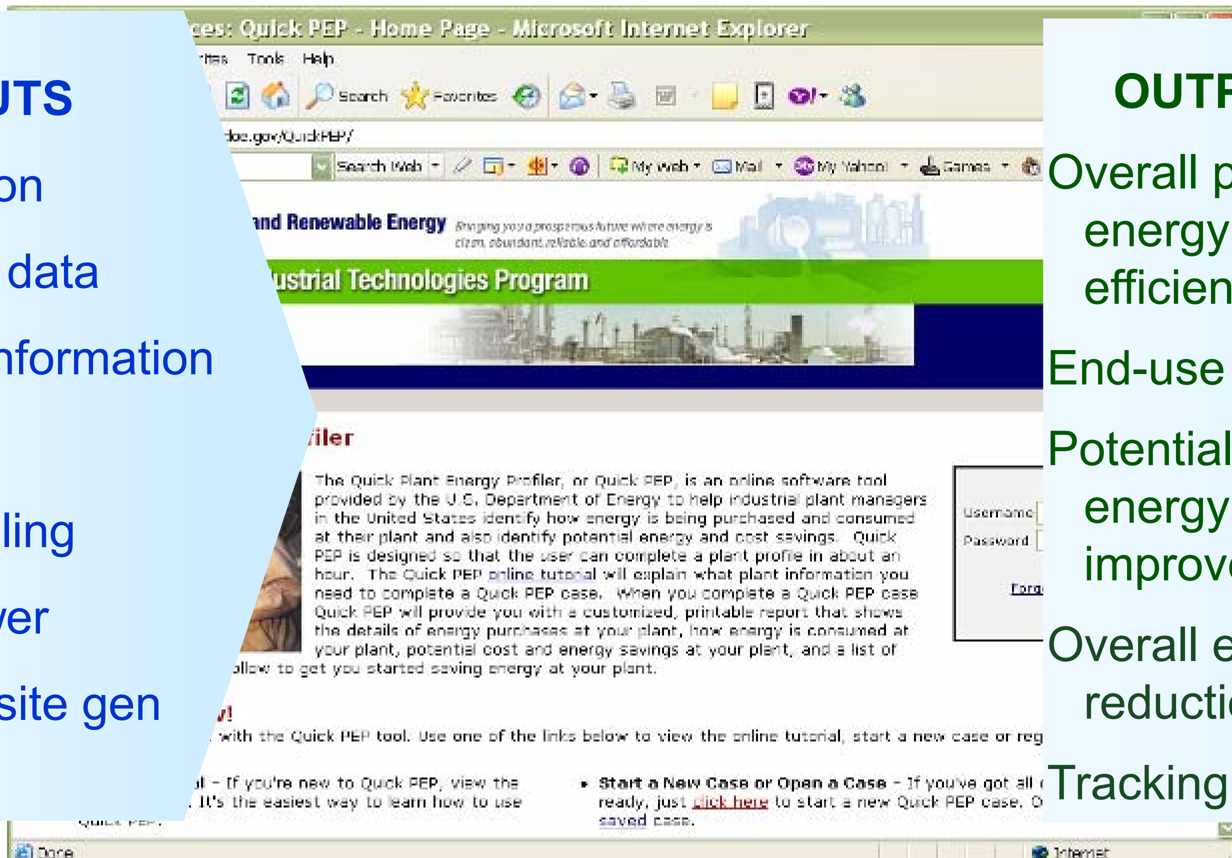
Air Management
- Hot/cold separation
- Environmental conditions
- RCI and RTI

Electrical Systems
- UPS
- PDU
- Transformers
- Lighting
- Standby gen.

IT-Equipment
- Servers
- Storage & networking
- Software

Cooling
- Air handlers/ conditioners
- Chillers, pumps, fans
- Free cooling

Save Energy Now On-line profiling tool: “Data Center Pro”



INPUTS

- Description
- Utility bill data
- System information
  - IT
  - Cooling
  - Power
  - On-site gen

OUTPUTS

- Overall picture of energy use and efficiency
- End-use breakout
- Potential areas for energy efficiency improvement
- Overall energy use reduction potential
- Tracking capability

Steps to Saving Energy:

Energy Profiling
↓
Subsystem Assessment

- Assessments conducted by owners and engineering firms using DOE tools
- Tools provide uniform metrics and approach

↓
Detailed Engineering Audit
↓
Engineering Design
↓
Retrofit/RCx Implementation

- Audits, design and implementation by engineering firms and contractors

↓
Savings Validation (M&V)
↓
Documentation

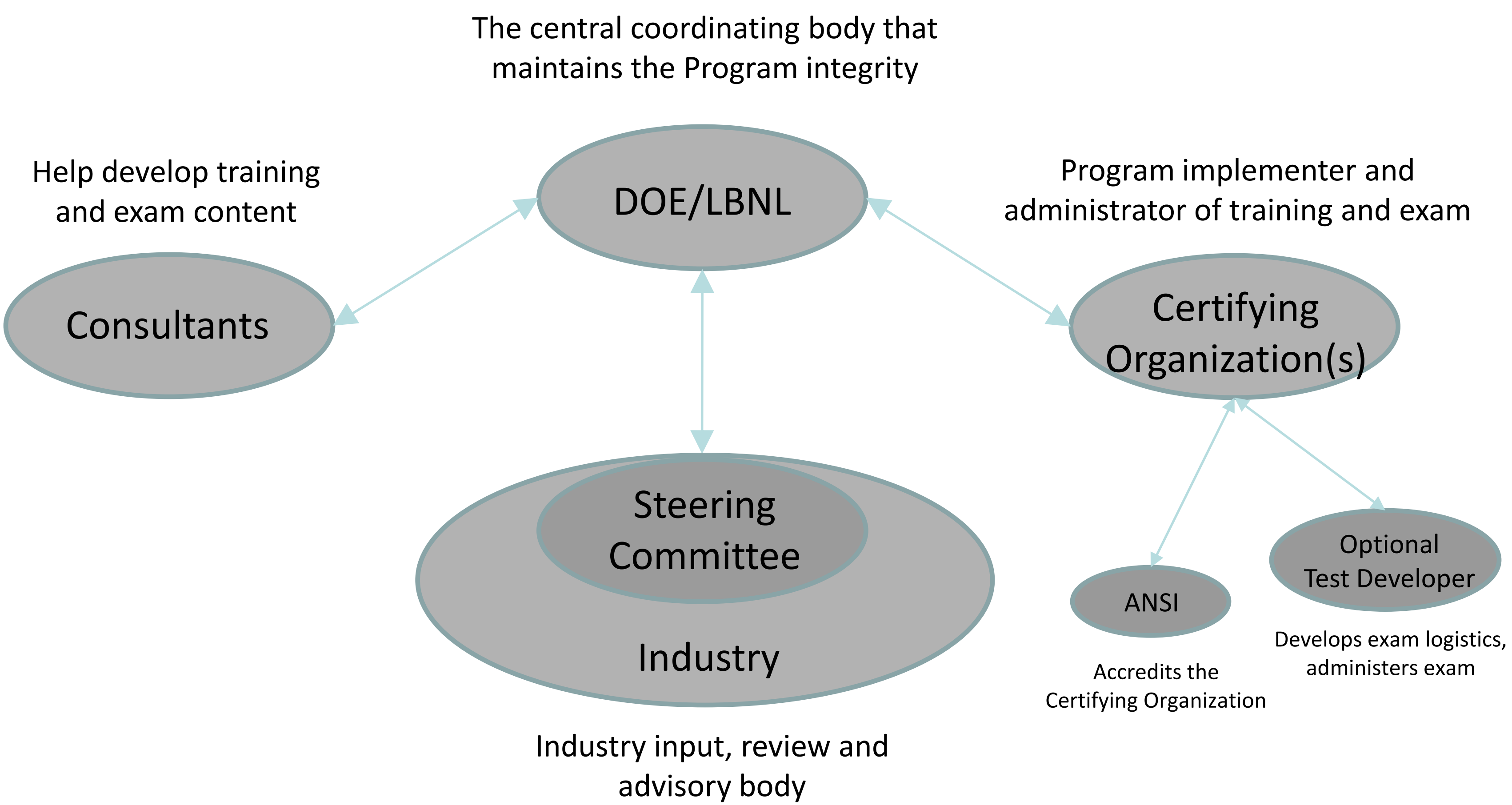
- M&V by site personnel and eng firms
- DOE tools used to document results, track performance improvements, and disseminate best practices

Data Center Certified Energy Practitioner

The data center industry and DOE are partnering to develop a certification process leading to practitioners qualified to evaluate the energy status and efficiency opportunities in data centers.

Key objective: Raise the standards of those involved in energy assessments of data centers to accelerate energy savings in the dynamic and energy-intensive marketplace of data centers.

DC-CEP Organizational Structure



Save ENERGY Now

Save ENERGY Now

<u>DOE Data Center program</u>

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Federal Energy Management Program

Mandates under EISA 2007 For Green IT

Energy Management Requirements

- All Federal agencies to reduce overall building energy usage (by 3% annually)

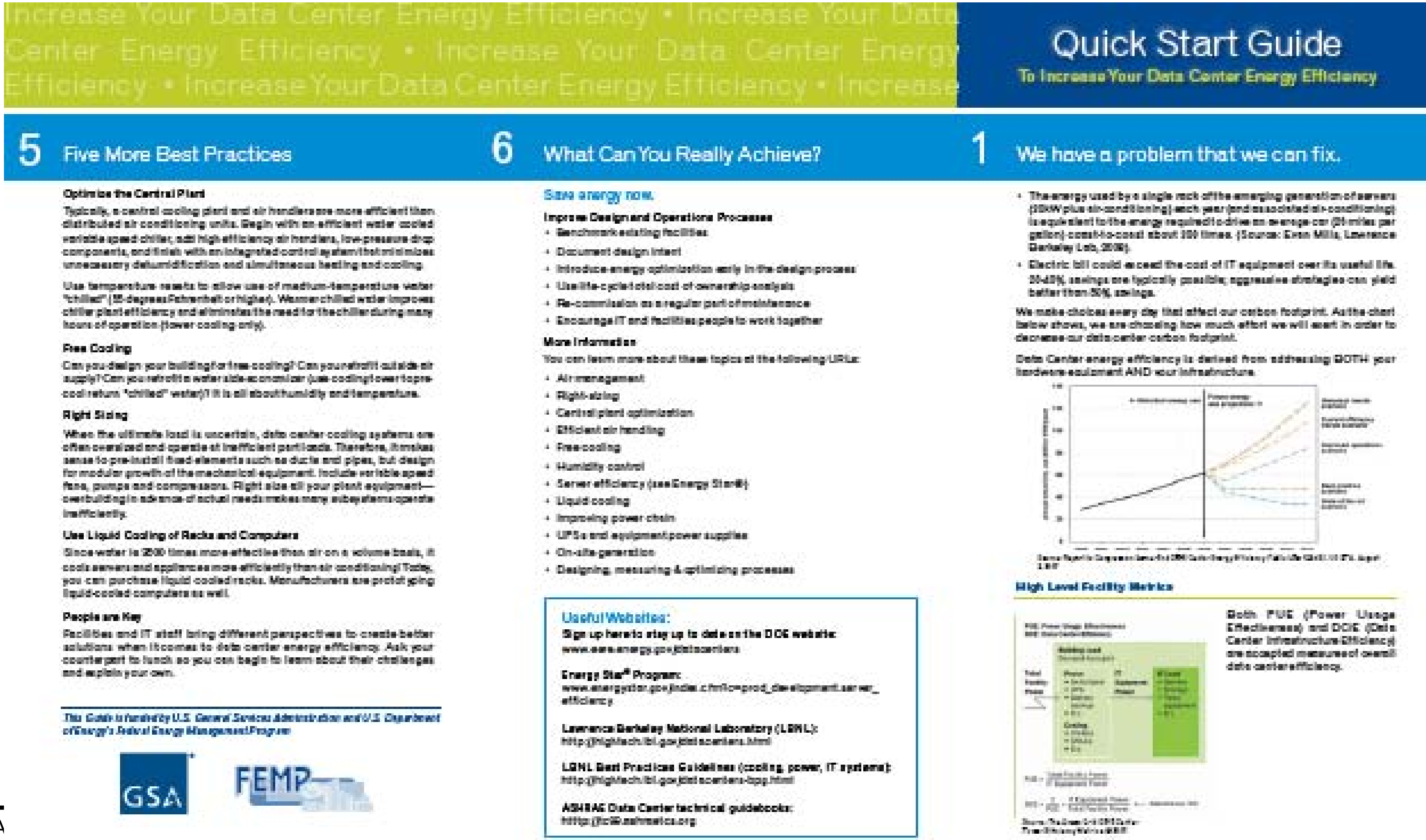
Fossil Fuel Consumption Reduction in Buildings

- All Federal buildings to be designed to use less fossil fuel energy, including fossil fuel to generate electricity
- Energy used for process loads (including servers) to be included
- 55% initial reduction, rising to 100% fossil fuel reduction by 2030

Federal Energy Management Program DC Services:

- **Technical Assistance (in partnership with GSA and others)**
  - Implementation of DC Pro Tool Suite
  - Project planning and early design
- **Training (in partnership with GSA and others)**
  - Webinars
  - Workshops at GovEnergy and Labs21 Conferences
- **Access to funding sources**
  - Energy savings performance contracts
  - Utility energy savings contracts
- **Development of best practice case studies and other tools**
- **Procurement specifications (starting with servers and UPS)**
- **Federal Energy Management Program awards**

FEMP/GSA Partnership



Increase Your Data Center Energy Efficiency • Increase Your Data Center Energy Efficiency • Increase Your Data Center Energy Efficiency • Increase Your Data Center Energy Efficiency • Increase

Quick Start Guide

To Increase Your Data Center Energy Efficiency

5 Five More Best Practices

Optimize the Central Plant

Typically, a central cooling plant and air handlers are more efficient than distributed air conditioning units. Begin with an efficient water cooled variable speed chiller, add high efficiency air handlers, low-pressure drop components, and finish with an integrated control system that minimizes unnecessary dehumidification and simultaneous heating and cooling.

Use temperature resets to allow use of medium-temperature water "chilled" (55 degrees Fahrenheit or higher). Warmer chilled water improves chiller plant efficiency and eliminates the need for the chiller during many hours of operation (tower cooling only).

Free Cooling

Can you design your building for free-cooling? Can you retrofit outside air supply? Can you retrofit a water side-economizer (use cooling tower to precool return "chilled" water)? It is all about humidity and temperature.

Right Sizing

When the ultimate load is uncertain, data center cooling systems are often oversized and operate at inefficient part-loads. Therefore, it makes sense to pre-install fixed elements such as ducts and pipes, but design for modular growth of the mechanical equipment. Include variable speed fans, pumps and compressors. Right size all your plant equipment—overbuilding in advance of actual needs makes many subsystems operate inefficiently.

Use Liquid Cooling of Racks and Computers

People are Key

This Guide is funded by U.S. General Services Administration and U.S. Department of Energy's Federal Energy Management Program

GSA FEMP

6 What Can You Really Achieve?

Save energy now.

Improve Design and Operations Processes

- Benchmark existing facilities
- Document design intent
- Introduce energy optimization early in the design process
- Use life-cycle total cost of ownership analysis
- Re-commission as a regular part of maintenance
- Encourage IT and facilities people to work together

More Information

You can learn more about these topics at the following URLs:

- Air management
- Right-sizing
- Central plant optimization
- Efficient air handling
- Free cooling
- Humidity control
- Server efficiency (see Energy Star®)
- Liquid cooling
- Improving power chain
- UPSs and equipment power supplies
- On-site generation
- Designing, measuring & optimizing processes

Useful Websites:

Sign up here to stay up to date on the DOE website:

Energy Star® Program:

Lawrence Berkeley National Laboratory (LBNL):

LBNL Best Practices Guidelines (cooling, power, IT systems):

ASHRAE Data Center technical guidebooks:

1 We have a problem that we can fix.

Data Center energy efficiency is derived from addressing BOTH your hardware equipment AND your infrastructure.

High Level Facility Metrics

DOE's Own Efforts:

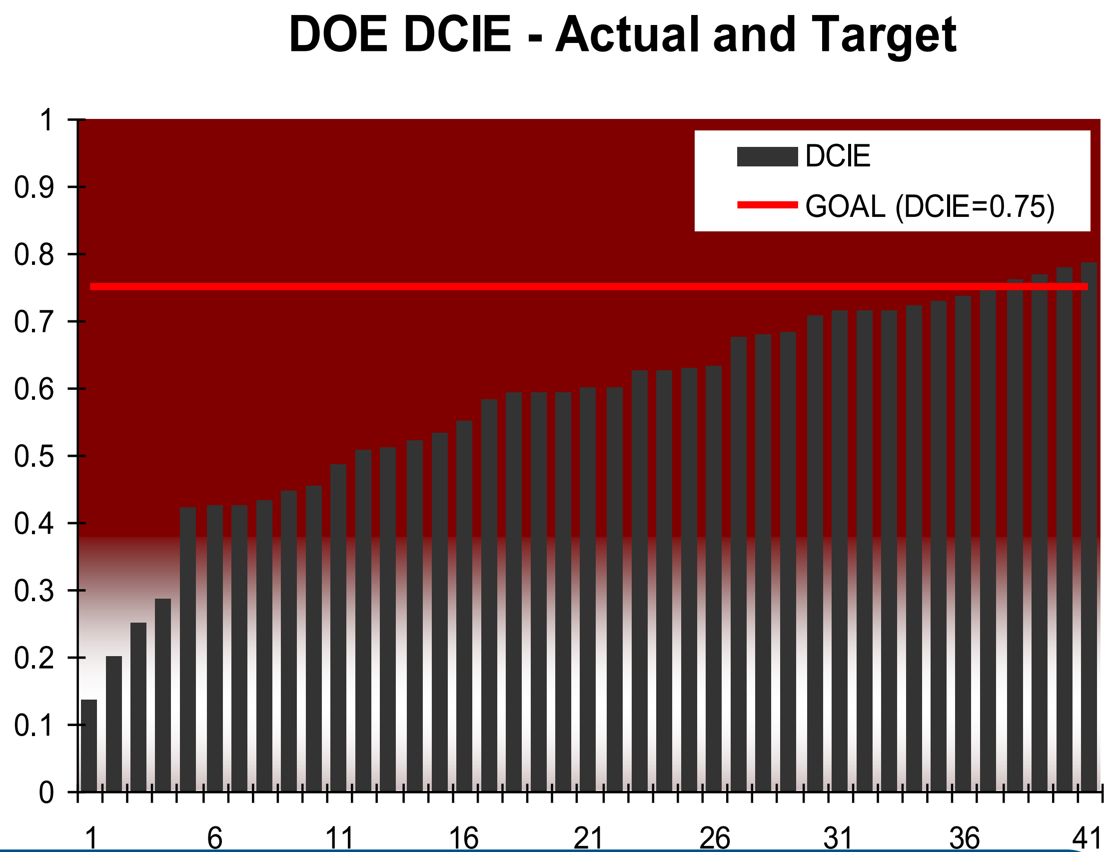
Gathered energy use data from 41 data centers

Encouraging sites to use DC Pro

Set Goal: Increase DCIE from 0.57 to 0.75

Headquarters Assessments

- Consolidation
- Servers configuration
- Wireless Sensors and Controls Demonstration



Data centers throughout the Federal Government need to adopt similar goals!

Data Center Working Groups Collaboration

The Federal Partnership for Green Data Centers

- An Inter-Agency forum to exchange ideas, develop policy guidance & tools to improve data center performance

High Performance Computing Working Group

- A forum for sharing information on best practices in scientific computing
- Includes members from the public and private sectors

Keeping Up with FEMP

Visit the FEMP Website for:

- Program Activity Information
- News Updates, Announcements & Policy Initiatives
- Upcoming Workshops & Training Events

http://www.eere.energy.gov/femp/

Data Centers Page:

http://www.eere.energy.gov/team/data_centers.html

For more information and to get involved:

Contact:

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What is ENERGY STAR?

- A voluntary public-private partnership program

US EPA Activities for Datacenters

Developing Datacenter Rating Tool for ENERGY STAR

Energy STAR specification for servers

Evaluating enterprise data storage, UPS, and networking equipment for possible Energy STAR product specs

ENERGY STAR: Data Center Rating Goals

Build on existing ENERGY STAR platform with similar methodology (1-100 scale)

Usable for both stand-alone data centers and data centers housed within office or other buildings

Assess performance at building level to explain how a building performs, not why it performs a certain way

ENERGY STAR label to data centers with a rating of 75+

Rating based on data center infrastructure efficiency

- Ideal metric would be measure of useful work/energy use.
- Industry still discussing how to define useful work.

Energy Star Data Center

See: www.energystar.gov/datacenters

Contact: Michael Zatz, EPA ENERGY STAR zatz.michael@epa.gov

Energy Star Servers

See
http://www.energystar.gov/index.cfm?c=new_specs.enterprise_servers

www.energystar.gov/productdevelopment

Contact: Andrew Fanara, EPA, Fanara.andrew@epa.gov

Industrial Technologies Program
- Tool suite & metrics for baselining
- Training
- Qualified specialists
- Case studies
- Recognition of high energy savers
- R&D - technology development

Federal Energy Management Program
- Workshops
- Federal case studies
- Federal policy guidance
- Information exchange & outreach
- Access to financing opportunities
- Technical assistance

GSA
- Workshops
- Quick Start Efficiency Guide
- Technical Assistance

Industry
- Tools
- Metrics
- Training
- Best practice information
- Best-in-Class guidelines
- IT work productivity standard

EPA
- Metrics
- Server performance rating & ENERGY STAR label
- Data center benchmarking

Links to Get Started

DOE Website: Sign up to stay up to date on new developments:
www.eere.energy.gov/datacenters

Lawrence Berkeley National Laboratory (LBNL):
http://hightech.lbl.gov/datacenters.html

LBNL Best Practices Guidelines (cooling, power, IT systems):
http://hightech.lbl.gov/datacenters-bpg.html

ASHRAE Data Center technical guidebooks: http://tc99.ashraetcs.org/

The Green Grid Association – White papers on metrics:
http://www.thegreengrid.org/gg_content/

Energy Star® Program:
http://www.energystar.gov/index.cfm?c=prod_development.server_efficiency

Uptime Institute white papers: www.uptimeinstitute.org

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www.tc99.ashraetcs.org